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Empirical validations of the DOE-2.1E building simulation software for daylighting and economizer controls

Peter Gregory Loutzenhiser
Iowa State University

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Empirical validations of the DOE-2.1E building simulation software for daylighting and economizer controls

by

Peter Gregory Loutzenhiser

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Mechanical Engineering

Program of Study Committee:
Gregory M. Maxwell, Major Professor
Stephen B. Vardeman
Ron M. Nelson

Iowa State University

Ames, Iowa

2003

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Graduate College
Iowa State University

This is to certify that the master's thesis of

Peter Gregory Loutzenhiser

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

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Chapter 1: Introduction

During the past 20 years, building simulation software programs have been and continue to be developed to model the energy interaction between building mechanical, lighting and electrical systems with building structures. Government laboratories like Lawrence Berkley Lab (LBL), Los Alamos National Lab, National Renewable Energy Lab (NREL), Oak Ridge National Lab (ORNL), Berkeley Solar Group (BSG), and the Sustainable Buildings Industries Council (SBIC) have participated in the development of building simulation software. These efforts have produced software which include: Energy+, DOE 2.1 (all versions), Blast, and Energy 10. Private companies like Trane and Carrier have also developed simulation software, which include: TRACE 600 and 700, and HAP. Building simulation software can be a valuable tool in the building design phase of any project.

Validations of building simulation software are an important facet of the development process. These undertakings provide confirmation to the software developers and users that the predictions from the software are meaningful. There are three general types of computer program validations: analytical, comparative, and empirical methods.

The analytical methods compare the results from building simulation software with results found for simple cases with known analytical solutions. For example, two-dimensional conduction at steady state may be modeled with a computer simulation and compared with the LaPlacian analysis. The comparative validation method poses the same problem to different computer programs and then compares the results. For empirical validation, comparisons are made between measured parameters from an actual building with results from simulation software.

The validations performed for this research used the empirical method of validation. Empirical validation can be performed at various levels for building simulation software. These include structure, equipment and systems, and whole buildings. The goal of this research was to integrate the structure, equipment and systems into one analysis and validate the interactions between these components with respect to the configuration of the whole building. To undertake such a project, the facility requires quality construction, good documentation, flexibility for change, controlled utilization, instrumentation, and a data acquisition system. To couple the results from the facility to the building simulation

software, the building must have a weather station that can measure temperature, humidity, pressure, wind speed and direction, solar irradiation (direct-normal and total), and illuminance. The building designed specifically for this type of undertaking is the Energy Resource Station (ERS).

A series of tests were performed at the ERS to validate certain aspects of the DOE-2.1E building simulation software. DOE-2 was developed primarily by LBL. The latest version of the software was released in May 2000. For the validation studies, the measurements taken during the test were used to calculate and compare empirical quantities to parameters simulated by a DOE 2.1E model. These tests and validations were performed in conjunction with the International Energy Agency (IEA) Task 22 Subtask D. The study focused on two control schemes: daylight controls for office spaces and airside economizer control for the air-handling units.

1.1 Daylight Controls

Daylight control schemes have become popular for exterior spaces. The control schemes use solar gain and ambient light to reduce the energy consumption required by lights and space cooling. There are two types of daylighting controls simulated in DOE-2.1E. One simulates the effect of movable exterior and interior shades that cover the fenestration while the other simulates the effect of dimmable ballasts on the lighting electrical power usage.

In non-daylighting controlled space, the lights operate at the installed capacity when the lights are turned on. For daylighting controlled space, the electrical power supplied to the lights is reduced as the available ambient light (daylight) levels increase. Typically, dimmable ballasts are used to reduce the electrical power to the room lights. The dimmable ballasts respond to a signal from a daylighting controller, which utilizes a light sensor for input. The light sensor, which is often mounted on the ceiling with a downward view, measures the light level at a prescribed point (reference point). The reference point is often chosen to be a working surface, such as a table or desktop. The daylighting controller compares the measured light level to the light level set-point value and adjusts the dimmable ballast accordingly. It is possible to turn the room lights off completely when ambient light levels are sufficient to meet the space needs.

Daylight-controlled spaces reduce the building energy requirements in two ways: reduced lighting energy and reduced cooling load. When a space requires cooling, heat given off by electric lights adds to the overall cooling load on the building. This thermal energy must be removed by the building's air-conditioning system. Any reduction in the heat from the lights will have a reduction in the cooling system energy consumption. On the other hand, heat from the lights might be considered to be a positive effect if the space requires heating. Heat from the lights helps offset the amount of thermal energy that must be supplied by the building's heating system; however, because of several interacting factors, it is more efficient to heat the space with the building's heating system rather than the electric lights.

For the tests performed at the ERS, the control scheme was developed using the building control software at the test facility and Li-Cor light sensors mounted on the tables of the "office spaces". This deviated from the conventional concept of controlling the lights from the ceiling. This was done primarily to compare the illuminance measured from the experiment to the simulated parameters from DOE-2.1E.

1.2 Air-side Economizer Controls

Typically, the economizer control strategy is enabled in the fall and spring when cooler outside air can supplement or replace the cooling required for the system. An airside economizer control is used to control a fraction of the outdoor air in the supply air. This fraction is modulated with an outdoor air damper, re-circulating air damper, and an exhaust damper. The dampers are configured so that the system can modulate between the minimum outside air value and 100% of the supply air (Krakow et al, 2000). The fixed damper position is usually adjusted so that ventilation requirements for the building are achieved. Several control schemes are used for the air-side economizer. These include:

- Enabling the air-side economizer when the outdoor air dry-bulb temperature is below a specified value of supply air temperature.
- Enabling the air-side economizer when the return air temperature exceeds the outdoor air dry-bulb temperature.
- Enabling the air-side economizer when the return air enthalpy exceeds the outdoor enthalpy.

The economizer tests performed for this study used a VAV system with a fixed supply air temperature and a minimum outdoor air damper position. The economizer control was enabled when the return air dry-bulb temperature exceeded the outdoor dry-bulb temperature.

Chapter 2: Literature Review

A great deal of research has been done that is relevant to this study. A summary of some of the research pertaining to daylighting validations and economizer controls are contained in this section.

2.1 Daylighting

A lot of work has been done to empirically validate daylighting simulation software. Daylighting software is typically in one of three forms: stand alone daylight analysis, building simulation software that includes daylighting options (i.e. DOE-2.1E), and daylighting software designed to be incorporated in building simulation software.

Daylight Software Analyses

A series of validations were performed using software designed to predict the illuminance of a structure with various geometrical configurations. In a report for the International Energy Agency Task 21, subtask C, empirical validations were performed for case studies using Superlite, Radiance, and Superlink (Galasiu et al, 1998). Models of the respective software were constructed and the results were compared with illuminance measurements for varying sky conditions and times of the year.

Daylighting Validations with DOE-2.1

DOE-2.1E was used to generate a building simulation of the ERS for this research. The focus for this daylight study was to validate the how the daylighting subroutine from the simulation software integrated with the other aspects of the software (i.e. the VAV system control) for a diffuse window treatment. Other daylighting simulations were performed at the ERS using different window treatments, and building set points. Lee (1999) performed several daylighting tests without window treatment on the test room windows for a VAVRH system and controlled the lights from a sensor mounted in the ceiling. Because of the relatively high magnitude of the illuminance entering the space, Lee found that the lights were at minimum capacity the when the sun entered the room. Thus, Lee's predictions for light power were very accurate despite discrepancies in his illuminance predictions.

Kuiken (2002) did a similar study with DOE-2.1E using mini-blinds for the test room window treatment. The tests were performed using a VAVRH system with electric reheat. The minimum airflow rate for the tests was relatively high and coupled with no induced sensible load; the system behaved like a constant volume system. Kuiken found that the DOE-2.1E simulation under-predicted the illuminance at the reference point, which caused over-predictions in the light power.

Daylight validations were also performed by the Florida Solar Energy Center (Shrum et al 1996). A trailer contained office sized rooms was used to validate DOE-2.1E with mini-blinds and no window treatment. The tests were performed over an extended period of time and compared with results from a DOE-2.1E model of the facility. The lighting energy reduction ranged from 24% to 45%. The DOE-2.1E predicted quantities with mini-blinds that varied from the empirical results from 6% to 18% depending on the office configuration. Better results were seen between the DOE-2.1E predicted quantities and the empirical quantities when the windows were left uncovered. These results varied from 1% to 7% depending on the test configuration. The results included daylight interactions but did not simulate other HVAC interactions associated with daylighting.

After the release of the daylighting facet of DOE-2.1, validations were performed in the LBL against scale model illuminance measurements. Different sky conditions were created using a laboratory sky simulator. Comparisons from the predicted values and the sky simulator tended to be less than 15% (Winkelmann et al, 1985).

A less rigorous validation is being pursued by the Iowa Energy Center for the Iowa Association of Municipal Utility (IAMU) building located in Ankeny, Iowa. The building was first modeled in DOE-2.1E and then built to incorporate lighting energy conservation strategies modeled in the DOE-2.1E simulation. Currently, a data-acquisitions system monitors the light energy. Weather data measured at the ERS is then used to validate a DOE-2.1 model on a monthly basis. As of yet, no results from this endeavor are available.

Daylighting Software Designed to be Incorporated into Building Software

With the advent of more complicated fenestrations system, conventional methods of describing the window properties have become more complex. With single pane clear

windows, it was possible make general estimations concerning the visible transitivity and the shading coefficient. Trying to model more complicated windows using these characteristics leads to significant errors.

McCluney (1991) writes that no longer are general approximations appropriate for hourly performance building simulation calculations. For complicated window glazings, the author recommends that angular-dependent values for the calculation of solar heat gain and visible transmissivity be used in lieu of traditional shading coefficients and normal (to the window surface) visible transmissivity measurements. This angular dependence also affects the temperature distribution of the windows, which ultimately impacts the u-values. The u-value is an important quantity when calculated heat conduction calculation through windows.

LBL has released a new version of their Windows software, Windows 5.1, software to replace Windows 4.1 software. The purpose of this software is to model the complex fenestrations properties. These programs deviate from the conventional concept of modeling windows using normal transmittance and a shading coefficient.

Currently, the Windows 5.1 software does not interact as well with DOE-2.1E as Windows 4.1. A glazing with similar properties as the test room windows was used from a library contained in DOE-2.1E. The results from this library were generated from the Window 4.1 software. Although the Windows Software accurately simulates complicated fenestration systems, there have been no additions to the software that allow similar analyses to be performed with installed interior window shading. DOE-2.1E currently models all shading devices (including mini-blinds) as diffuse shades (Wilkemann et al, 1985).

Given a latitude and longitude and weather data with direct-normal and total irradiation, the DOE-2.1E building simulation software can distinguish between direct and diffuse light entering a bare window. The software can also calculate the angle of incidence of the direct light. The daylighting subroutine for the DOE-2.1E building simulations program distinguishes between direct and diffuse light entering the space for the bare window calculation and thus can account for angular dependents (Wilkemann et al, 1985).

DOE-2.1E allows the simulators to use the conventional shading coefficient method to predict solar gain and the solar heat gain method that accounts for angular dependents. In a study performed by Reilly et al. (1995) using Chicago weather conditions in June, calculated

solar gain comparisons were made using the shading coefficient method and the solar heat gain method accounting for angular dependence. The study used a single clear window glazing and a double clear window glazing with two different wind conditions. The wind conditions for the cases were 3.3 m/s and 0 m/s. When the wind speed was 3.3 m/s, the shading coefficient method under-predicted the solar heat gain for the single clear glazing by 10% and over-predicted the solar heat gain for the double clear glazing by 17%. Poorer results were seen when the wind speed was 0 m/s. The shading coefficient method the under-predicted single clear glazing by 35% and over-predicted the double clear glazing by up to 12%.

2.2 Economizer

Based on the literature search for the present research, there have been no validations efforts with regard to any building simulation software. The validation efforts for systems operating in economizer mode primarily focus on control issues associated with maintaining the outside airflow rates. Krakow et al (2000) did extensive work in describing quantities associated with damper controls and making comparisons between nonlinear and linear damper linkage with regard to system fan energy. A numerical simulation was used along with empirical results to compare the types of damper controls.

Avery (1989) writes about problems associated with VAV system in the economizer mode. Avery also makes general recommendations for damper sizing, maintaining a minimum airflow rate when the economizer mode by using empirical measurements.

Although little was written with regard to the economizer control, a large amount has been written about maintaining a fixed minimum outside airflow for a VAV system. With increased concern regarding indoor air quality, a lot of attention has been focused on maintaining a constant pressure difference across the outside air damper. Elovitz (1995) suggests various control strategies for maintaining a constant minimum outside airflow rate. These include: sequencing return and supply fans together, direct measurement of outside air, and fan tracking for VAV systems.

Shroeder et al (2000) recommend that for a VAV system, an alternate means rather than fixing outside air damper system should be employed to maintain the outside airflow rate.

Pressure differences throughout a VAV system cause the level of outside air to vary for different conditions. It is important to maintain a fixed minimum airflow to maintain indoor air quality for the zones.

Chapter 3: Facility Layout

The ERS was built in 1995 as a demonstration and test facility owned by the Iowa Energy Center to test various energy reducing control strategies in the HVAC field. The building control system can measure hundreds of system related parameters. The facility also has a weather station and a pyrheliometer and a parometer used for solar measurements. The following narrative describes the facility, and daylight and economizer test configurations. Construction and configuration of the building are described more in-depth in *Description of the Iowa Energy Center Energy Resource Station: Facility Update III* (Price and Smith, 2000).

3.1 Facility Description

The ERS is located on the Des Moines Area Community College in Ankeny, Iowa and is operated and owned by the Iowa Energy Center. The latitude and longitude of the facility are 41.75 degrees north latitude and 93.7 degrees west longitude, respectively. The facility is 289 meters above sea level. Figure 3.1.1 shows a photograph of the building taken from the east side.



Figure 3.1.1: The Energy Resource Station.

The building is comprised of eight test rooms, a computer room, offices, two classrooms and other rooms necessary for the support and operation of the facility. A floor plan of the facility is shown in Figure 3.1.2. The ERS is equipped with three air-handling units, two of which are identical and serve the test rooms. The test rooms designated as “A” or “B” are

served by separate air-handling units, while the rest of the facility is controlled by the third air-handling unit. The test rooms are grouped in pairs to provide simultaneous side-by-side testing of different control schemes with “identical” thermal loads. Three of the four pairs of test rooms are located at the perimeter of the building (east, south, and west) while the other pair is located in the interior of the building. The building is situated so that one wall faces true north.

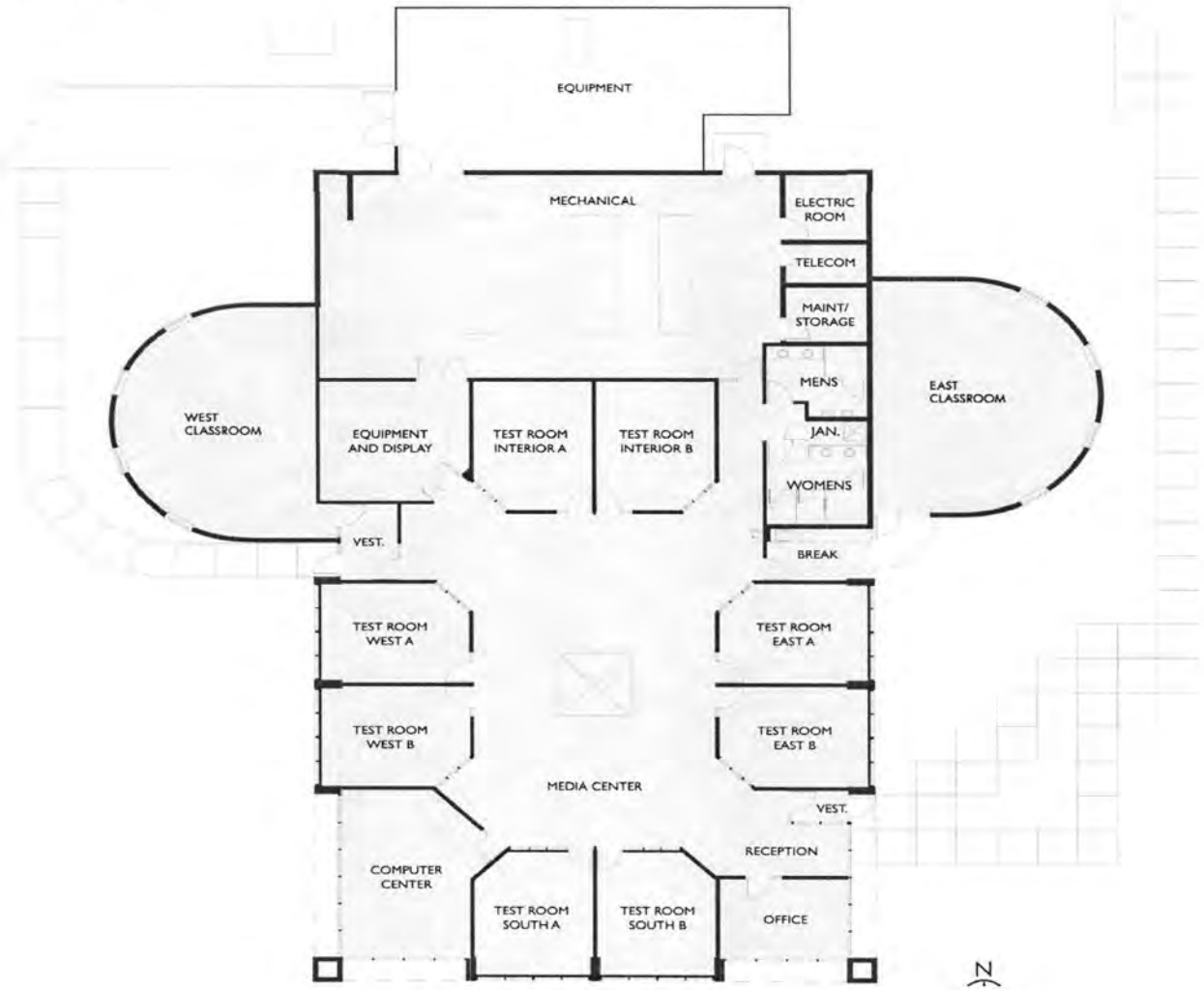


Figure 3.1.2: A floor plan of the Energy Resource Station.

3.2 Daylight Test Configuration

Two daylight tests were performed at the ERS for this validation. Test Case I was conducted over a five-day period from April 18 to April 25, 2002, and Test Case II was run over a five-day period from January 29 to February 2, 2003. The “A” and “B” systems were configured using Variable-Air-Volume Reheat (VAVRH) with hydronic reheat coils. Dimmable ballasts were enabled in the “B” test rooms, while the lights in the “A” were run at installed test capacity. The general setup and properties for the test rooms and the air-handling units included the following parameters:

- Window configuration.
- Lighting configuration.
- Baseboard heat configuration.
- Zone controls and set points.
- Zone lighting and baseboard heat schedules.
- System controls and set points.

These parameters are described in greater detail in the following sections.

Window Configuration

The windows of the exterior test rooms were covered with white muslin drapes. This provided diffuse shading that matched the design constraints of the daylight element of the DOE-2.1 building simulation. The drape properties were experimentally quantified and the test room window properties were taken from information provided by the window manufacture. These properties are contained in Table 3.2.1. During the tests, the drapes were weighted down on the windowsill to ensure a uniform fit over the windows.

Lighting Configuration

Six fixtures are typically used in the test rooms at the ERS. For the daylight tests, two fixtures were removed and four remaining light fixtures were reconfigured to provide and even distribution of illuminance to the test rooms. De-lamping was done because the test rooms were over-lit and the reconfiguration provided a more realistic light level at the reference point. Figure 3.2.1 shows this new lighting distribution for the east test rooms. The measurements were taken at night to negate the effect of supplemental ambient light

passing through the windows during the day. Measurement intervals were determined by making a grid on the floor that corresponded with the ceiling tile grid configuration. The light level measurements were taken throughout the test rooms 0.7239 m from the floor to correspond to the reference plane height.

During the daylight tests, a lighting sensor mounted on the table with 180° field of view was used to control the dimmable ballasts in each test room. The position of the sensor with respect to the table is shown in Figure 3.2.3. A photograph showing a test room configuration for a daylight test can be seen in Figure 3.2.2.

For both tests, the control strategy was to maintain a fixed illuminance at the reference point for the exterior “B” test rooms. During the day, ambient light entered the space through the windows. When ambient light subsidized the artificial light at the reference point, the lights were adjusted to maintain the prescribed light level at the reference point. The lights were turned off when the ambient light entering the space exceeded the set point and the system could not dim the lights further. The reference set points for the daylight tests were as follows:

- Case I: 645.8 Lux
- Case II: 700.0 Lux

Table 3.2.1: Window and drape properties for the exterior test rooms.

	Visible Light				Solar Energy		U Value		Relative Heat Gain	Shading Coefficient
	Exterior Appearance	Color/Type	Trans %	Reflectance % In % Out	Trans %	Reflect (out) %	Winter Night-time	Summer Day-time		
Windows	Transparent	Clear	81	14 14	66	11	2.75	3.13	563	0.854
Drapes	Diffuse	Muslin White	55	NA NA	56	NA	NA	NA	NA	62

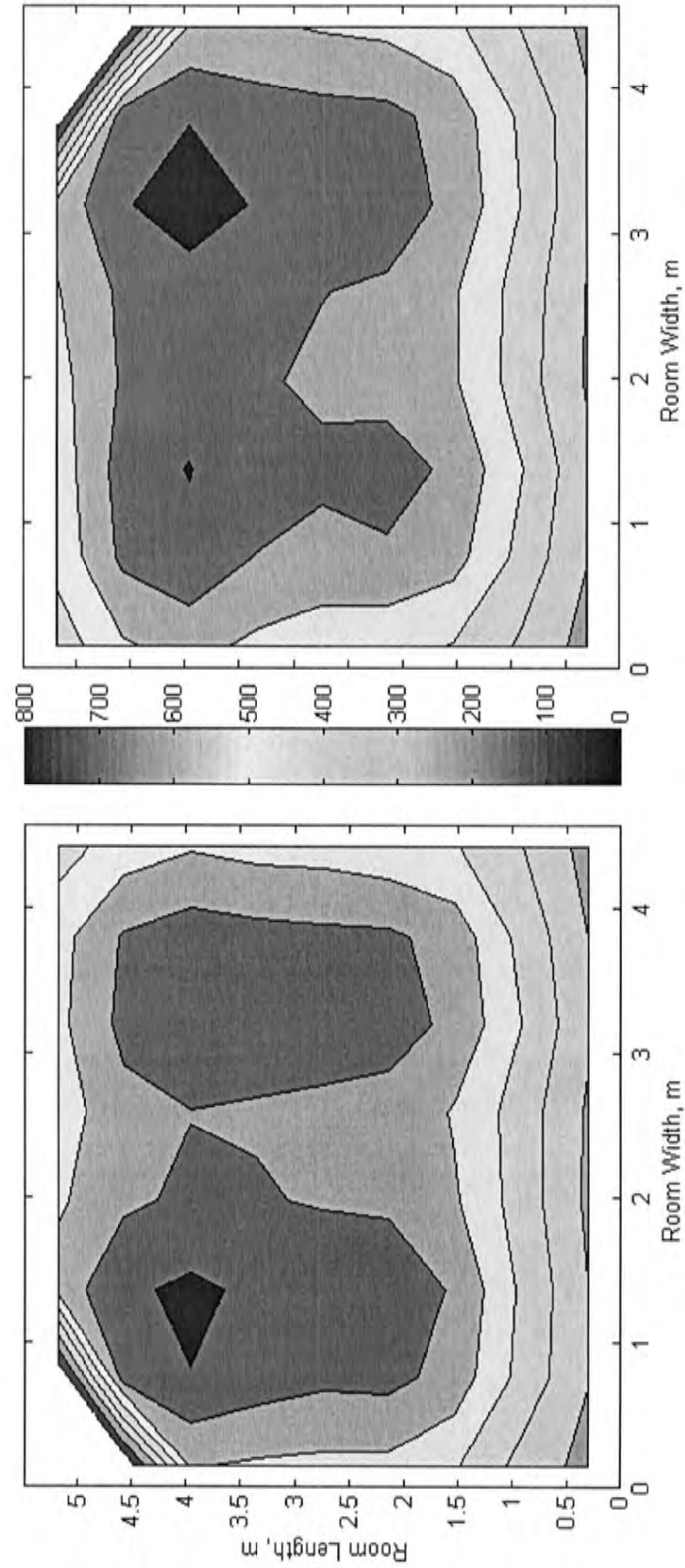


Figure 3.2.1: Illuminance distributions for the east test rooms in Lux prior to Case I.

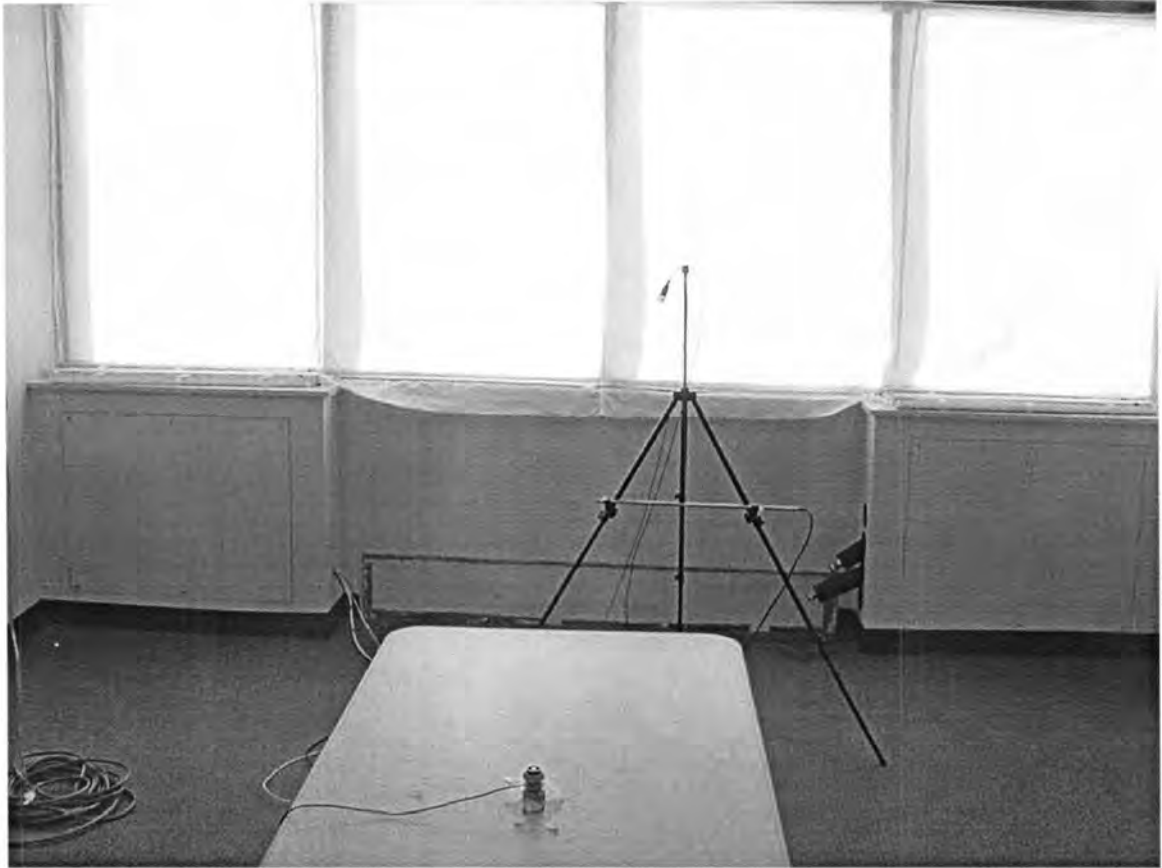


Figure 3.2.2: Test room configuration for the daylight tests.

In the exterior “B” test rooms, the lights were adjusted to maintain a prescribed illuminance in the table. The dimensions of this reference point with respect to the rest of the test room are shown in Figure 3.2.3.

The maximum light power for the all the test rooms and the minimum light power for the exterior “B” test rooms for Cases I and II are shown in Table 3.2.2. Prior to the tests, measurements were taken in the exterior “B” test rooms using only the artificial light in test configuration to correlate the lighting power and the illuminance at the reference point (the light sensor mounted on the table) for the building simulations. Table 3.2.3 contains the numerical comparisons, while Figure 3.2.4 contains a graphical representation of measurements used for Case I. Due to light decay in the fluorescent bulbs, a separate

measurement was taken prior to Case II. The numerical comparisons and graphical representations are contained in Table 3.2.4 and Figure 3.2.5, respectively.

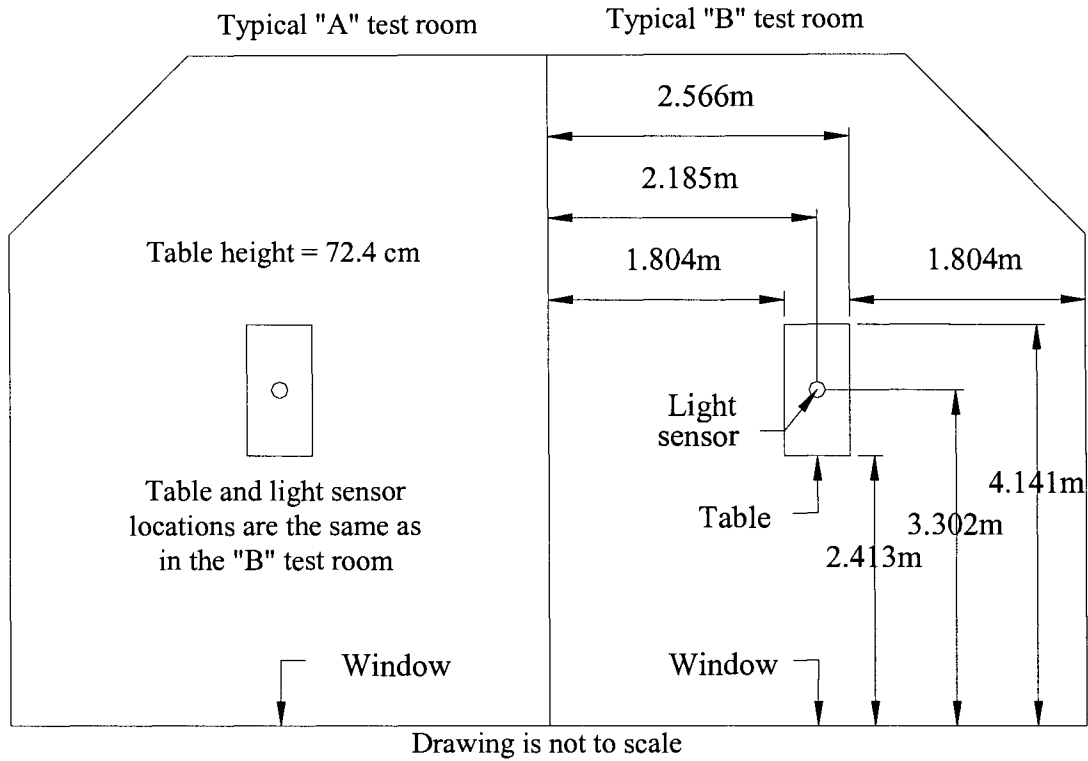


Figure 3.2.3: Light sensor reference point location.

Table 3.2.2: Maximum light power and minimum light power for the "B" rooms.

Test Room	Maximum Light Power, W		Minimum Light Power, W	
	Case I	Case II	Case I	Case II
East "A"	358.5	353.5	NA	NA
East "B"	359.5	350.5	89.1	91.8
South "A"	359.0	358.5	NA	NA
South "B"	367.5	359.0	89.4	91.8
West "A"	361.5	353.0	NA	NA
West "B"	364.0	356.8	85.8	89.0
Interior "A"	354.3	355.8	NA	NA
Interior "B"	360.0	358.0	NA	NA

Table 3.2.3: Reference point illuminance values and light power for the “B” rooms Case I.

East “B” Test Room		South “B” Test Room		West “B” Test Room	
Light Power, W	Illuminance, Lux	Light Power, W	Illuminance, Lux	Light Power, W	Illuminance, Lux
0.0	0.0	0.0	0.0	0.0	0.0
89.1	27.4	89.4	27.2	85.8	27.0
90.3	31.8	90.9	32.7	86.9	32.4
131.3	116.5	132.0	114.4	129.6	118.9
173.1	217.0	174.4	212.4	173.1	221.5
214.3	315.2	215.9	307.8	215.0	311.0
253.4	428.9	255.8	419.1	255.0	437.6
296.8	532.1	297.3	520.4	297.3	543.2
332.0	632.7	339.0	637.1	335.8	641.8
357.5	688.2	366.3	694.3	360.5	702.3
359.5	693.6	367.5	694.3	364.0	707.7
358.5	688.2	366.5	694.3	360.8	702.3

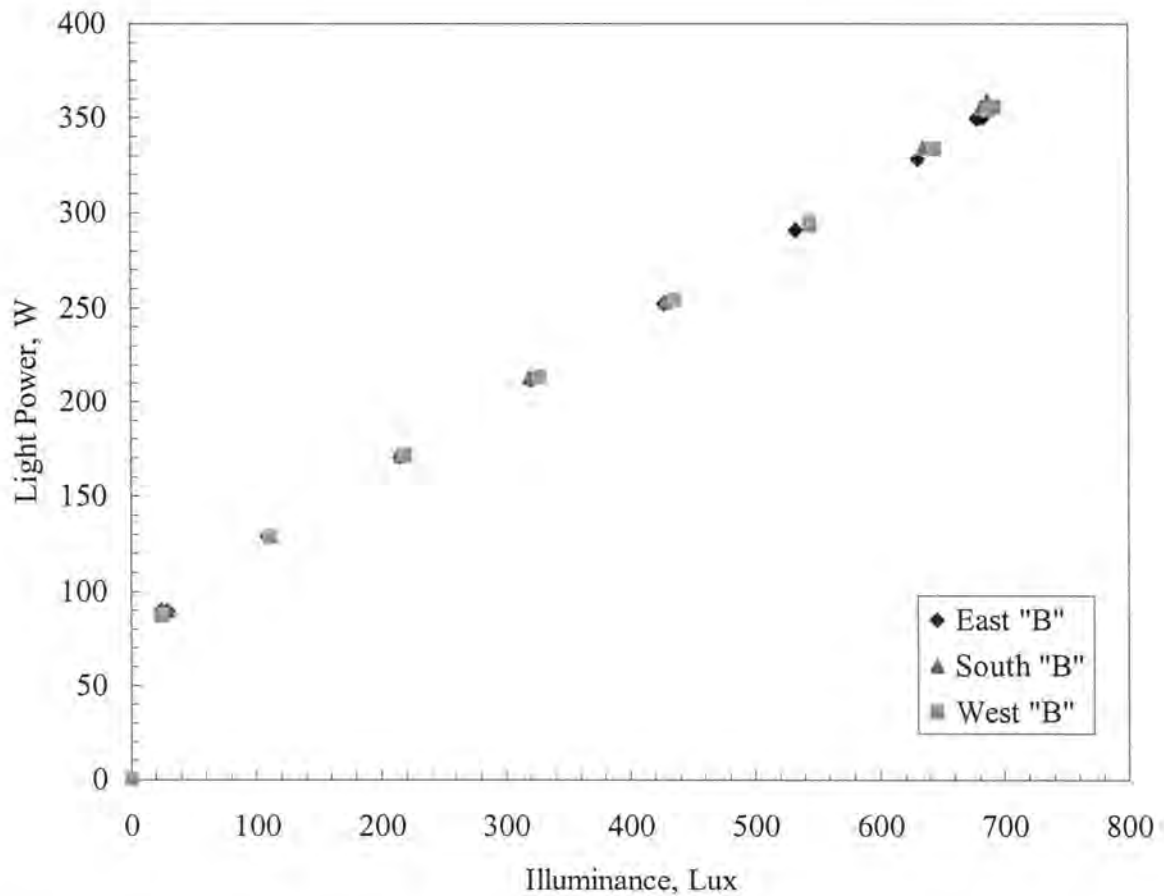


Figure 3.2.4: Reference point illuminance versus light power for the “B” rooms Case I.

Table 3.2.4: Reference point illuminance values and light power for the “B” rooms Case II.

East “B” Test Room		South “B” Test Room		West “B” Test Room	
Light Power, W	Illuminance, Lux	Light Power, W	Illuminance, Lux	Light Power, W	Illuminance, Lux
0.0	0.0	0.0	0.0	0.0	0.0
90.1	24.0	90.3	24.7	87.6	24.5
89.6	29.3	89.6	30.2	87.0	24.5
129.0	108.8	129.6	111.9	128.6	111.1
170.8	214.9	171.6	215.6	171.6	219.3
211.8	320.9	212.9	319.2	213.5	327.6
252.1	426.8	253.3	428.2	254.4	435.9
291.0	532.9	294.3	544.1	295.0	544.1
328.3	631.0	334.3	635.7	333.5	644.1
350.3	678.5	355.8	681.8	355.8	692.6
349.3	678.5	355.0	681.8	354.0	687.6

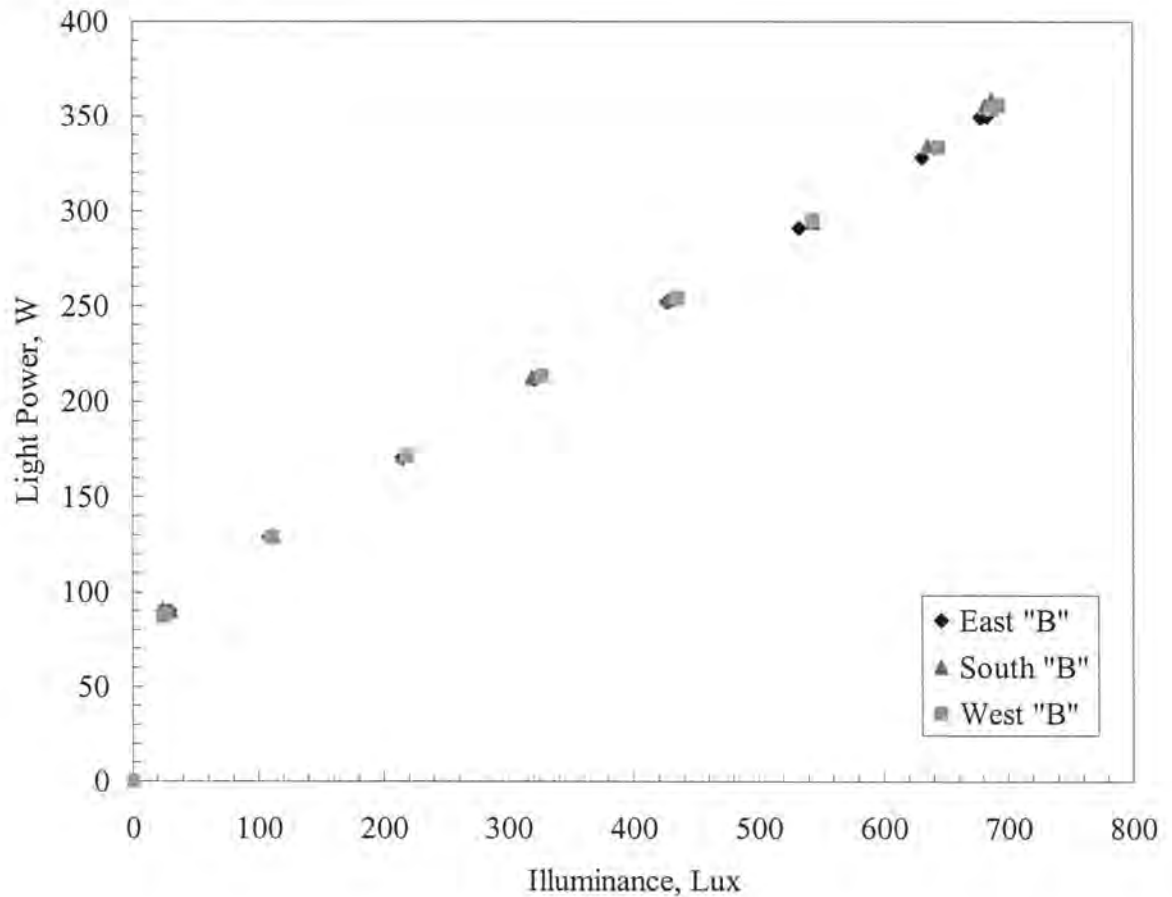


Figure 3.2.5: Reference point illuminance versus light power for the “B” rooms for Case II.

Baseboard Heat Configuration

Baseboard heat was used in the test rooms to provide an additional sensible load to the space indicative of occupancy. The ERS test rooms are equipped with two stages of electric baseboard heat. For the daylight experiments, both stages of baseboard heat were used. Table 3.2.5 provides the power measurements for each respective test room for each stage.

Table 3.2.5: Baseboard heat power for the test rooms.

Room	Stage 1 Power, kW	Stage 2 Power, kW	Total Power, kW
East "A"	0.89	0.89	1.78
East "B"	0.89	0.88	1.77
South "A"	0.89	0.88	1.77
South "B"	0.88	0.89	1.77
West "A"	0.86	0.86	1.72
West "B"	0.89	0.89	1.78
Interior "A"	0.87	0.90	1.77
Interior "B"	0.90	0.90	1.80

Zone controls and set points

For both daylight tests, the test rooms were configured in a similar manner. The thermostat controlled space temperature. The thermostat set points for heating and cooling were as follows:

- Heating thermostat set point: 22.2 °C
- Cooling thermostat set point: 22.8°C

For Case I, the maximum and minimum airflow rates for the exterior test rooms were configured as follows:

- Maximum flow rate: 1,699 m³/hr
- Minimum flow rate: 340 m³/hr

And the maximum and minimum airflow rates for the interior test rooms were configured as follows:

- Maximum airflow rate: 934 m³/hr
- Minimum airflow rate: 340 m³/hr

Discrepancies in the measured airflow rates were noticed after Case II. Several alternate airflow measurements were taken using a pitot tube traverse and flow hoods. For the

comparable conditions, the alternate measurement reflected a lower airflow rate than what was observed from the ERS data acquisition system. Correlation between the building control measurements taken during the test and corrected values were developed and the results for the room airflow rates were post-processed. Because the errors in the measured results varied from test room to test room, no general correlation could be implemented. Therefore, individual room correlations were used to correct the airflow measurements, which resulted in varying test room minimum airflow rates. The minimum and maximum airflow rates are shown in Table 3.2.6.

Table 3.2.6: Maximum and minimum test room airflow rates for Case II.

Test Room	Maximum Airflow Rate, m ³ /hr	Minimum Airflow Rate, m ³ /hr
East "A"	1,699	298
East "B"	1,699	323
South "A"	1,699	306
South "B"	1,699	283
West "A"	1,699	291
West "B"	1,699	307
Interior "A"	934	310
Interior "B"	934	298

Zone lighting and baseboard heat schedules

The lights and the baseboard heat were scheduled to turn off and on for intervals on time for each test. The lights in each test were set to turn on an hour prior to sunrise and turn off an hour after sun set; therefore, the lighting scheduled varied between tests. The lighting schedules for both tests are shown in Table 3.2.7.

Table 3.2.7: Lighting test schedule.

Time, hr	Lights, On/Off	
	Case I	Case II
0:00	Off	Off
1:00	Off	Off
2:00	Off	Off
3:00	Off	Off
4:00	Off	Off
5:00	On	Off
6:00	On	On
7:00	On	On
8:00	On	On
9:00	On	On
10:00	On	On
11:00	On	On
12:00	On	On
13:00	On	On
14:00	On	On
15:00	On	On
16:00	On	On
17:00	On	On
18:00	On	Off
19:00	On	Off
20:00	On	Off
21:00	Off	Off
22:00	Off	Off
23:00	Off	Off
24:00	Off	Off

Baseboard heat was also scheduled to turn on and off during the tests. The same schedule was used for both daylight tests and is shown in Table 3.2.8.

Table 3.2.8: Test room baseboard heat schedule.

Time, hr	Baseboard Heat, On/Off	
	Stage 1	Stage 2
0:00	Off	Off
1:00	Off	Off
2:00	Off	Off
3:00	Off	Off
4:00	Off	Off
5:00	Off	Off
6:00	Off	Off
7:00	Off	Off
8:00	On	On
9:00	On	On
10:00	On	On
11:00	On	On
12:00	On	On
13:00	On	On
14:00	On	On
15:00	On	On
16:00	On	On
17:00	Off	Off
18:00	Off	Off
19:00	Off	Off
20:00	Off	Off
21:00	Off	Off
22:00	Off	Off
23:00	Off	Off
24:00	Off	Off

System Controls and Set Points

During both tests, the “A” and the “B” systems were configured in a similar manner. For Daylight Case I, the interior “A” test room was not in control so the static pressure set point was increased for Daylight Case II. For both tests, the system controls were configured as follows:

- Heating schedule: always available.
- Cooling schedule: always available.
- Cooling control supply air temperature set point after the fan: 15.5 °C.
- Preheat: NOT available.
- Humidity control: NOT available.
- Economizer: disabled.

The system air for both the “A” and “B” systems was specified as follows:

- Supply airflow rate: maximum 5,777 m³/hr.
- Return air path: plenum
- Minimum outside airflow: 100% re-circulated.
- Duct air loss: negligible.
- Duct heat gain: 0.5 °C (Case I)
1.0 °C (Case II)

The fans were identically configured for the “A” and the “B” air-handling units for each test. But the set points and the fan curves varied between Cases I and II. The following configurations were used for the daylight tests:

- Supply air static pressure: 348.4 Pa (Case I)
547.4 Pa (Case II)
- Fan schedule: always on
- Supply fan control: 348.4 Pa (Case I)
547.4 Pa (Case II)
- Return fan control differential: 340 m³/hr offset
- Motor placement: In-air flow
- Fan placement: Draw-through

To estimate the temperature rise across the supply fan, a relationship between fan power and supply airflow rate was developed using empirical test data. The best description of fan power was found to be a second order polynomial. The relationship shown in equation 3.2.1 was used to estimate the temperature rise across the fan for Case I.

$$FP = 2 \times 10^{-7} Q^2 - 4.0 \times 10^{-4} Q + 0.7414 \quad (3.2.1)$$

where

FP is the fan power in kW.

Q is the supply airflow rate in m³/hr.

The coefficient of determination was 0.989, which provides strong support for the second-order polynomial fit. To further emphasize this relationship, Figure 3.2.6 contains plots of the data points and equation 3.2.1.

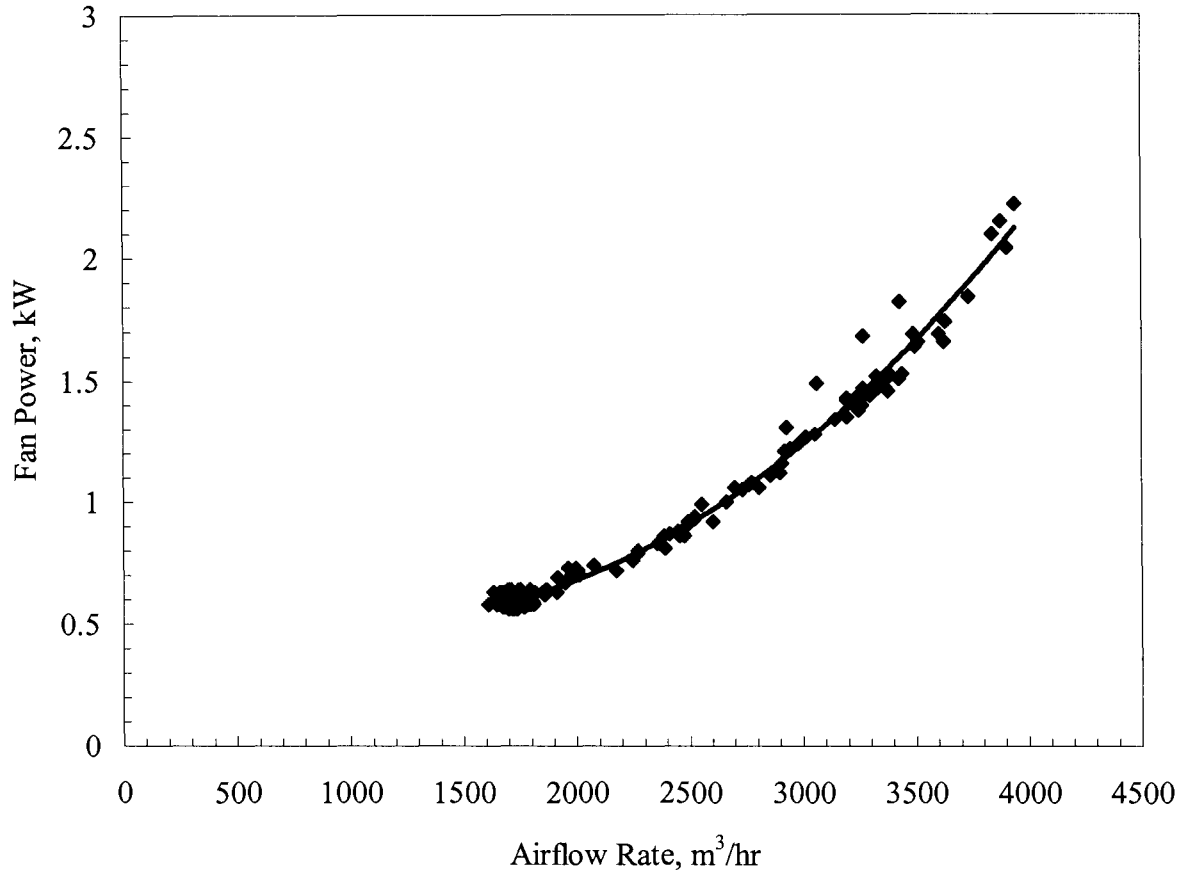


Figure 3.2.6: Supply air fan power versus airflow rate.

The increased pressure set point for the supply fan in Case II compared with Case I caused the fan curve to differ from Case I. Thus, the relationship between fan power and airflow rate is described by a different second-order polynomial fit shown in equation 3.2.2.

$$FP = 2.0 \times 10^{-7} Q^2 + 1.0 \times 10^{-4} Q + 0.6872 \quad (3.2.2)$$

The coefficient of determination was calculated to be 0.9972, which also indicates the effectiveness of the second-order polynomial fit describing the relationship between the airflow rate and fan power.

Air-side Economizer Configuration

One airside economizer test was performed at the ERS for this validation study. The test was conducted over a four-day period from May 2 to May 5, 2002. The “A” and “B” systems were configured using Variable-Air-Volume Reheat (VAVRH) with hydronic reheat. The economizer control was enabled on the “A” system. The system moved from the minimum damper position when the return air temperature exceeded the outdoor air temperature. The minimum damper position for both the “A” and “B” systems was 20% open. The general setup and properties for the test rooms and the air-handling units included the following parameters:

- Window configuration
- Lighting configuration.
- Baseboard heat configuration.
- Zone controls and set points.
- System controls and set points.

Window Configuration

For the economizer test, no treatment was applied to the windows. Window fenestration properties for the economizer test can be found in Table 3.2.1.

Lighting Configuration

For the economizer test, the room lights were operated according to a time of day schedule. When the lights were on, they operated at a constant power level. The electrical power used by the lights for each test room is shown in Table 3.3.1 while the operating schedule is shown in Table 3.3.2.

Table 3.3.1: Lighting capacity for the test rooms during the economizer test.

Test Room	Light Power, W
East “A”	544.0
East “B”	548.5
South “A”	536.5
South “B”	543.5
West “A”	463.5
West “B”	530.5
Interior “A”	533.5
Interior “B”	535.5

The lights were scheduled to come on and turn off at the same time each day during the economizer test. This schedule is shown in Table 3.3.2.

Table 3.3.2: Light schedule for the economizer test.

Time, hr	Lights, On/Off
0:00	Off
1:00	Off
2:00	Off
3:00	Off
4:00	Off
5:00	Off
6:00	Off
7:00	On
8:00	On
9:00	On
10:00	On
11:00	On
12:00	On
13:00	On
14:00	On
15:00	On
16:00	On
17:00	On
18:00	On
19:00	Off
20:00	Off
21:00	Off
22:00	Off
23:00	Off
24:00	Off

Baseboard Heat Configuration

One stage of baseboard heat was used to provide an additional sensible load to the space. The baseboard heat was scheduled on during the entire test. Table 3.3.3 contains the baseboard heat power by test room used for the economizer test.

Table 3.3.3: Baseboard heat ratings by test rooms.

Test Room	Baseboard Heat Rating, kW
East "A"	0.89
East "B"	0.89
South "A"	0.89
South "B"	0.88
West "A"	0.86
West "B"	0.89
Interior "A"	0.87
Interior "B"	0.90

Zone Controls and Set Points

The test rooms for both the "A" and "B" systems were configured identically. A thermostat located in each room controlled the hydronic reheat. The thermostat set points for heating and cooling were as follows:

- Heating thermostat set point: 22.2 °C
- Cooling thermostat set point: 22.8 °C

The maximum and minimum airflow rates for the exterior test rooms were set as follows:

- Maximum airflow rates: 1,699 m³/hr.
- Minimum airflow rates: 340 m³/hr.

The maximum and minimum airflow rates for the interior room were set as follows:

- Maximum airflow rates: 680 m³/hr.
- Minimum airflow rates: 340 m³/hr.

System Controls and Set Points

During both tests, the economizer control was enabled on the "A" system while the "B" system remained the fixed minimum damper position. Besides the economizer control on the "A" system, the systems were configured identically and described as follows:

- Heating schedule: always available.
- Cooling schedule: always available.
- Cooling control supply air temperature set point after the fan: 15 °C.
- Preheat: NOT available.

- Humidity control: NOT available.
- Economizer: enabled when the return air temperature exceeded the outdoor air temperature for the “A” system.

The system air for both the “A” and the “B” systems was specified as follows:

- Supply airflow rate: maximum 5,777 m³/hr.
- Return air path: plenum
- Minimum outside airflow: 20% damper position.
- Duct heat gain: 1.1 °C.

The fans were identically configured for the “A” and the “B” air-handling units. The following configurations were used for the economizer test:

- Supply air static pressure: 348.4 Pa.
- Fan schedule: always on.
- Supply fan control: 348.4 Pa.
- Return fan control differential: 90% of supply air.
- Motor placement: In-air flow.
- Fan placement: Draw-through.

To estimate the temperature rise across the supply fan, a prediction equation relating fan power and supply airflow rate was developed using empirical test data. The equation was a second order polynomial. The relationship shown in Equation 3.3.1 was used to approximate the temperature rise across the fan.

$$FP = 7 \times 10^{-8} Q^2 - 4.0 \times 10^{-5} Q + 0.319 \quad (3.3.1)$$

The coefficient of determination is 0.9927, which provides strong support for the second-order polynomial fit. To further emphasize this relationship, Figure 3.3.1 contains plots of the data points and Equation 3.3.1.

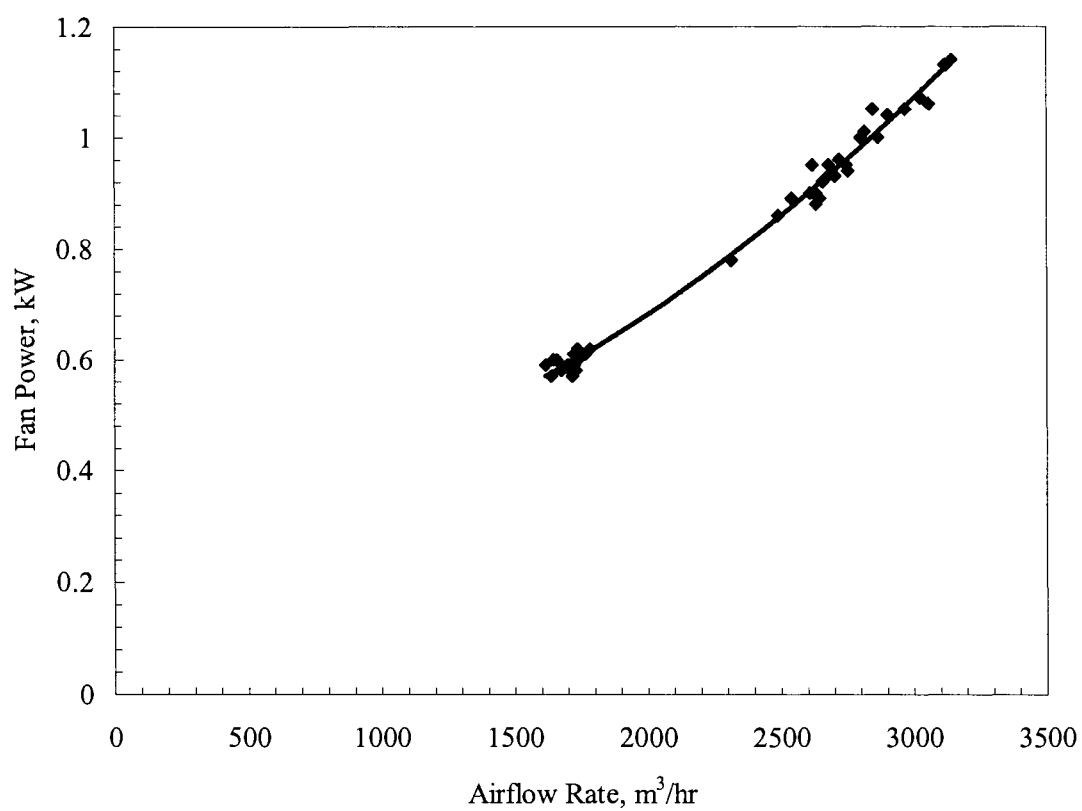


Figure 3.3.1: Fan power versus airflow rate for the economizer test.

Chapter 4: Descriptive and Comparative Quantities

In order to compare the results from DOE-2.1E with the experiments, statistical parameters and comparative statistics were calculated. Explanations of these parameters and the results from the tests are contained in this section.

The statistical parameters calculated were divided into two general groups: standard numerical summary and comparative statistics. These values were then used to calculate the building simulation error with respect to the experiment.

4.1 Standard Numerical Summary

The standard numerical summaries are the results that describe the individual measurement. These values include: arithmetic mean, standard deviation, and maximum and minimum values. These values were calculated for all parameters in the experiment as well as the building simulations.

The arithmetic mean was calculated using the relationship described in Equation 4.1.1.

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (4.1.1)$$

where

n is the number of samples of the parameter.

x_i is the individual values of the parameter.

The sample standard deviation was calculated using the relationship described in Equation 4.1.2.

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad (4.1.2)$$

The maximum value was calculated using the following relationship described in Equation 4.1.3.

$$x_{max} = \max(x_i) \quad (4.1.3)$$

The minimum value was calculated using the relationship described in Equation 4.1.4.

$$x_{min} = \min(x_i) \quad (4.1.4)$$

4.2 Comparative Statistics

A set of comparative statistics was calculated to compare the predicted building simulation values to those quantities measured at the ERS and calculated from the measurements. These statistics were valuable for comparing the models against each other relative to the data that were gathered at the ERS. These quantities included: average difference, maximum and minimum differences, average absolute difference, and root mean squared difference. A description of how these values were calculated is provided in this section.

The average difference was the difference between the measured parameter at a given instance in time and value predicted by the model at the same time. The quantity was normalized for entire test by taking the arithmetic mean of the difference. This quantity provides relevant summary information about how well the results from building simulation compared with the empirical results. This value was calculated using the relationship described in Equation 4.2.1.

$$\bar{D} = \frac{1}{n} \sum_{i=1}^n (E_i - P_i) \quad (4.2.1)$$

where

E_i is the measured experimental value at an instant in time.

P_i is the predicted value for the building simulations, which corresponds to the measured value.

The maximum difference was useful in comparing where the greatest error in magnitude occurred on an hour-by-hour basis. This quantity was calculated using the relationship described in Equation 4.2.2.

$$D_{\max} = \max |E_i - P_i| \quad (4.2.2)$$

The minimum difference was useful when comparing what the smallest error in magnitude on an hour-by-hour basis. This quantity was calculated using the relationship described in Equation 4.2.3.

$$D_{\min} = \min |E_i - P_i| \quad (4.2.3)$$

The absolute average difference is the absolute value of the difference between the measured parameter at a given instance in time and value predicted by the building for that same instant in time normalized over the entire test. This quantity reflects how well the building simulation predicts hour-by-hour results compared to the empirical results. This quantity was calculated using the relationship described in Equation 4.2.4.

$$|\overline{D}| = \frac{1}{n} \sum_{i=1}^n |E_i - P_i| \quad (4.2.4)$$

A root mean squared comparison is another valuable quantity when comparing the predicted results with the empirical results. This is a more conventional comparison that also accounts for differences without regard to positive or negative signs. This method also reflects how well the building simulation predicted hour-by-hour results compared with the experiment. The quantity was calculated using the relationship described in Equation 4.2.5.

$$D_{rms} = \sqrt{\frac{1}{n} \sum_{i=1}^n (E_i - P_i)^2} \quad (4.2.5)$$

Simulation Error

Two methods were used to quantify how the building simulation performed on an hour-by-hour analysis and over the duration of the experiments. Both parameters are important for the validation process. In the building design phase, where a simulation might be used to quantify energy savings by implementing or removing a hypothetical control scheme, it would be advantageous knowing that the building simulation does a good job predicting the annual energy usage. For other applications, it may be advantageous to accurately predict parameters on an hour-by-hour basis. The summary error calculated in Equation 4.2.6 is useful for comparing summary quantities.

$$SE = \frac{\sum_{i=1}^n (E_i - P_i)}{\sum_{i=1}^n E_i} \times 100\% \quad (4.2.6)$$

The instantaneous error calculated in Equation 4.2.7 was useful in comparing the experiment datum with the predicted values at a given instant in time.

$$IE = \frac{\sum_{i=1}^n |E_i - P_i|}{\sum_{i=1}^n E_i} \times 100\% \quad (4.2.7)$$

4.3 Experimental Uncertainty

The experimental uncertainty was calculated for each parameter measured at the ERS or calculated using measured values. For the temperature measurements, calibration information was used to estimate 95% uncertainty bands from a linear regression analysis. Ninety-five percent uncertainty bands were also calculated from corrected room airflow rates for Daylight Case II. The uncertainty associated with the measured values of the so-called gold standard for the airflow and temperature regression analyses and other parameters without extensive calibration information were estimated from manufacturers' product information and current literature. Some measurements contained error estimated using statistical analysis as well as some specified error from the manufacturer. For the manufacturer error, a 95% uncertainty interval was estimated by assuming a uniform distribution. The Pythagorean methodology was used to estimate the total experimental error. The total experimental error calculated in Equation 4.3.1. is the value recommended by BIPM/ISO *Guide* to account for all the errors in the experiment for a 95% uncertainty bound (Gleser, 1998).

$$\sigma = \sqrt{u^2 + \sum \left(\frac{1.96d^2}{3} \right)} \quad (4.3.1)$$

where

u is a 95% uncertainty band calculated using regression analysis.

d are all errors not found using statistical analyses (i.e. published manufacturer error).

Information regarding the linear analysis for the temperatures and the zone airflow rates for Daylight Case II are described in Appendix B.

Several parameters were not measured directly at the ERS, but were calculated from measured quantities. Therefore, the experimental uncertainty was a function of the parameters required to make this calculation. To estimate the 95% uncertainty limits, uncertainty analysis or propagation of error equation was used. The methods used to perform the calculations are contained in Appendix B.

Chapter 5: Daylight Test Results

Comparisons between what was measured at the ERS and simulated by DOE-2.1E for the daylight tests are contained in this section. An additional experiment was performed between the daylight tests to verify and quantify room stratification. These results are also described in this section.

5.1 Daylight Test Case I

The results from the daylight test performed from April 18 to April 22, 2002 are described in this section.

Weather Comparisons

Building simulation software are primarily driven by measured weather information, which in turn drives the zone loads, providing the hour-by-hour changes in the predicted values that correspond, in principle, to the governing relationships which drive heat transfer through the walls (conduction) as well as solar heat gain through the windows (radiation). The weather also drives the ventilation and infiltration loads. For a daylight validation using DOE-2.1E, the simulation predicted the illuminance at the reference point and varied the power to the lights. The simulation subroutine for the illuminance calculations was more accurate when both direct-normal and total irradiation were included in the weather file. DOE-2.1E can also make daylight calculations using different weather file formats that do not include irradiance measurements, but do include quantities like cloud cover. Coupled with the building location (longitude and latitude) and local time zone, an algorithm in the building simulation software calculates the position of the sun with respect to the building. Additional weather information required for the other predictors contained in the simulation include: outdoor air dry-bulb temperature, relative humidity, and ambient pressure. These quantities were all measured at the ERS and put into TMY (typical meteorological year) weather format. The weather information along with the inputs about the building configuration allowed the software to make prediction about zone and system operations.

Therefore, incorrect weather information can cause significant errors even in the best simulation software. For comparison purposes, weather output from the simulation was compared to the measured weather and calculated parameters (wet-bulb temperature) at the ERS for both daylight test cases. These parameters included: outdoor air dry-bulb temperature, wet-bulb temperature, direct normal irradiation, and total irradiation. Figure 4.1.1 provides graphical comparisons for the experiment and DOE-2.1E simulation for Case I.

The weather comparisons were useful to confirm the simulation used the correct weather information for calculations. There were several instances where an hour offset was found by comparing the simulation weather parameters to those from the experiment due to daylight saving time. The weather file was then updated to account for these shifts. General hypotheses concerning the loads and predictions can also be made using these plots. A useful quantity for predicting how the daylighting facet of the simulation will run is the direct normal irradiation. For Case I, Figure 5.1.1 indicates that first day of the test was partly cloudy, followed by two very cloudy days and finally two relatively sunny days. It was then expected there would be more dimming of the lights in the test rooms on the sunnier days. Additional weather information like dry-bulb temperature coupled with the irradiance measurements allows very general predictions pertaining to system and zone performances. The building simulations also contain specific building, and load characteristic which allow much more precise predictions.

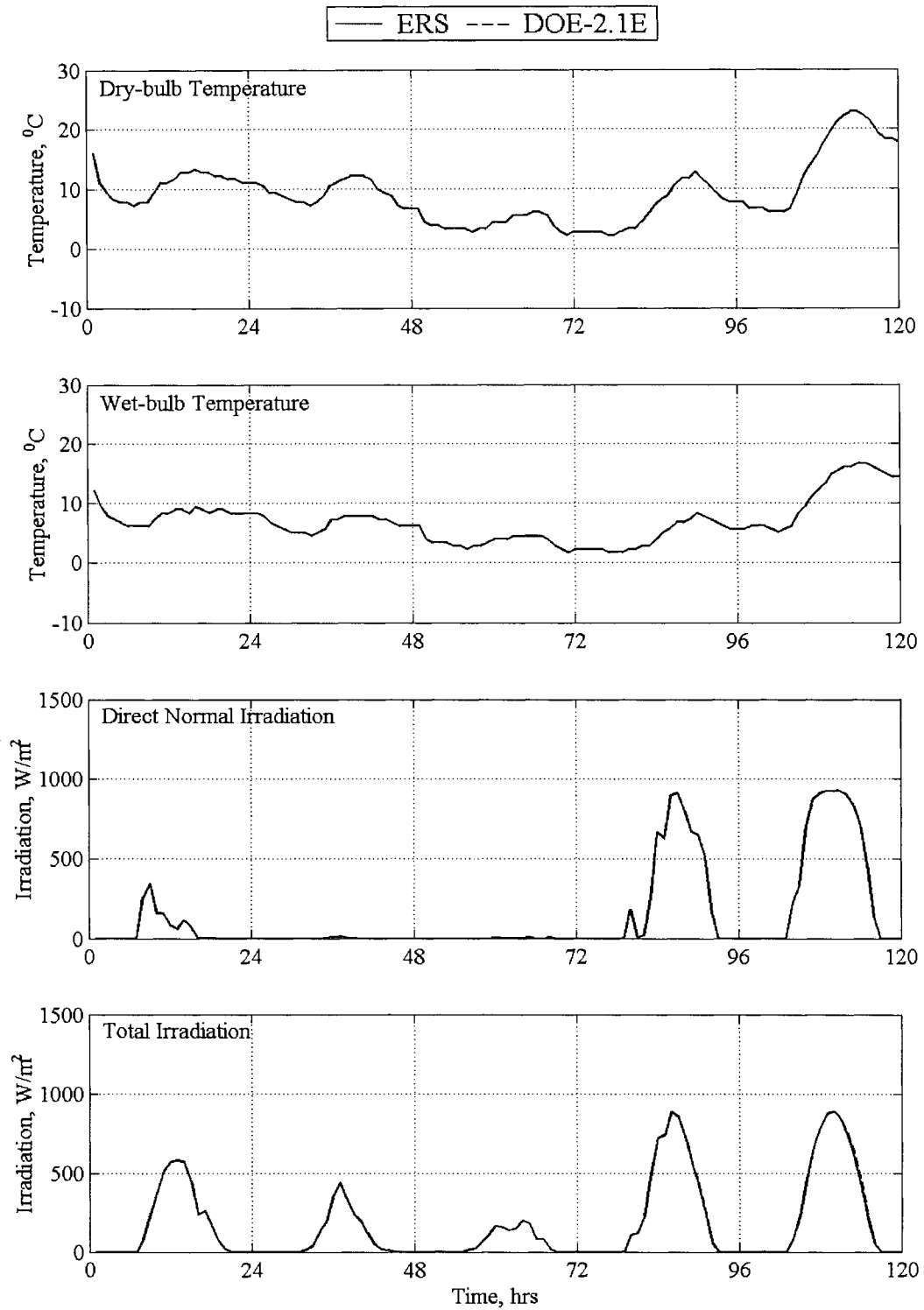


Figure 5.1.1: Simulation and experimental weather comparisons Case I.

Zone Comparisons

Zone comparisons were made for various parameters from the ERS and the DOE-2.1E simulations. The following parameters were compared:

- Zone illuminance at the reference point.
- Zone light power.
- Zone airflow rates.
- Zone reheat power.
- Zone temperature.

These parameters were measured and calculated for both the “A” and the “B” test rooms, despite the fact the dimmable ballasts for the lights were only enabled for the “B” test rooms.

Zone Illuminance at the Reference Point

During the tests, a Li-Cor sensor measured the illuminance at the reference point. For the exterior “B” test rooms, the building control system used the illuminance measured from the Li-Cor sensor to modulate the lights. The DOE-2.1E simulation predicted the light at the reference point due to daylight entering the zone through the windows rather than the sum of the daylight and artificial light. Therefore, measurement taken prior to the test and described in Section 3.2 relating light power and illuminance at the reference point due to artificial light were used to determine the fraction of measured daylight. The graphical depiction for the “A” test rooms Case I can be found in Figure 5.1.2.

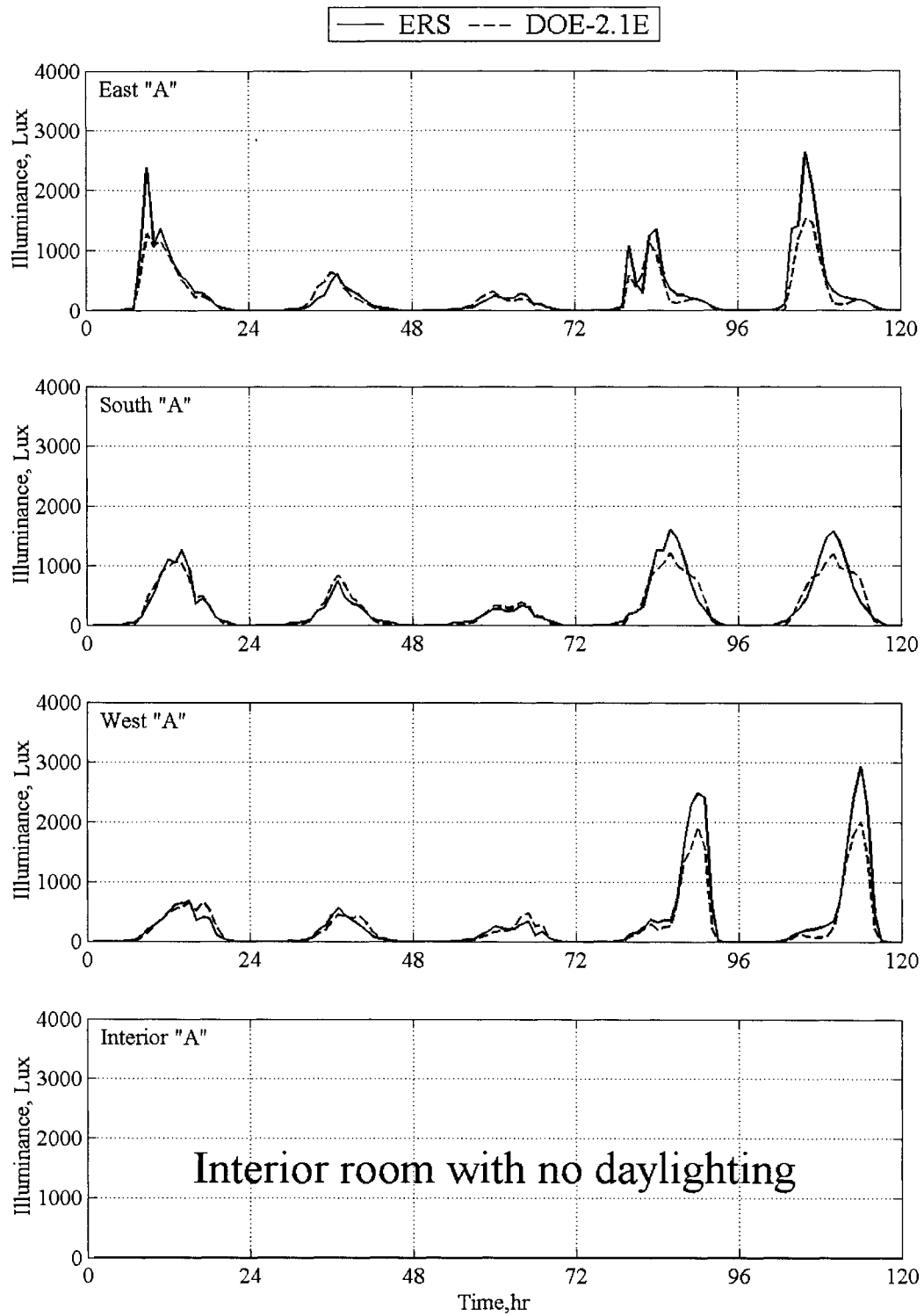


Figure 5.1.2: Illuminance comparisons at the reference point for the "A" rooms Case I.

On cloudy days and in the south test room, the predicted illuminance was consistent with the measured illuminance. When the test was performed, the path of the sun was relatively high in the sky. Thus the south test room was exposed to less direct sunlight than the east and west test rooms. On sunny days, the high magnitudes of light in the east and west test rooms caused large errors in the illuminance predictions. But on cloudy days and in the south test room, the DOE-2.1E software illuminance predictions were much closer to the experiment. Table 5.1.1 contains the statistical parameters for the illuminance at the reference points for the “A” test rooms.

Table 5.1.1: Statistical comparisons for the illuminance in the “A” rooms Case I, in Lux.

Statistics	East “A”		South “A”		West “A”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	265.9	205.9	279.7	267.8	283.6	230.5
σ	39.4	NA	41.3	NA	40.3	NA
s	482.2	342.2	413.1	361.3	571.7	420.7
x_{\max}	2641.0	1526.4	1604.0	1205.2	2940.0	2015.0
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
\bar{D}	NA	60.0	NA	12.0	NA	53.1
D_{\max}	NA	1114.6	NA	462.5	NA	925.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	82.3	NA	69.3	NA	82.1
D_{rms}	NA	198.1	NA	126.8	NA	190.5
SE	NA	29.1	NA	4.5	NA	23.0
IE	NA	40.0	NA	25.9	NA	35.6

From Table 5.1.1, the arithmetic mean indicates that the measured illuminance from the experiment for the east test room were larger than those predicted by DOE-2.1E. The variations primarily occurred on the sunnier days of the experiment.

Smaller simulation and instantaneous error indicate the predicted values from DOE-2.1E for the south test room compared better with the experiment. This was probably due to the fact the south test room was not exposed to the magnitude of sunlight seen by the east and west test rooms.

The simulation and instantaneous errors for the west test room were similar to the errors seen in the east test room. This was primarily due to the fact that the morning and evening

sky condition were similar when large amount of light entered the space. Given a cloudy morning and a sunny afternoon, there would probably be a larger error for the west test room compared to the east test room or vice versa. All the calculated average differences for the illuminance exceeded their 95% uncertainty bounds.

There was no daylighting in the interior test rooms; therefore no statistical comparisons were performed. Similar comparisons for the illuminance were made for the “B” test rooms Case I shown in Figure 5.1.2.

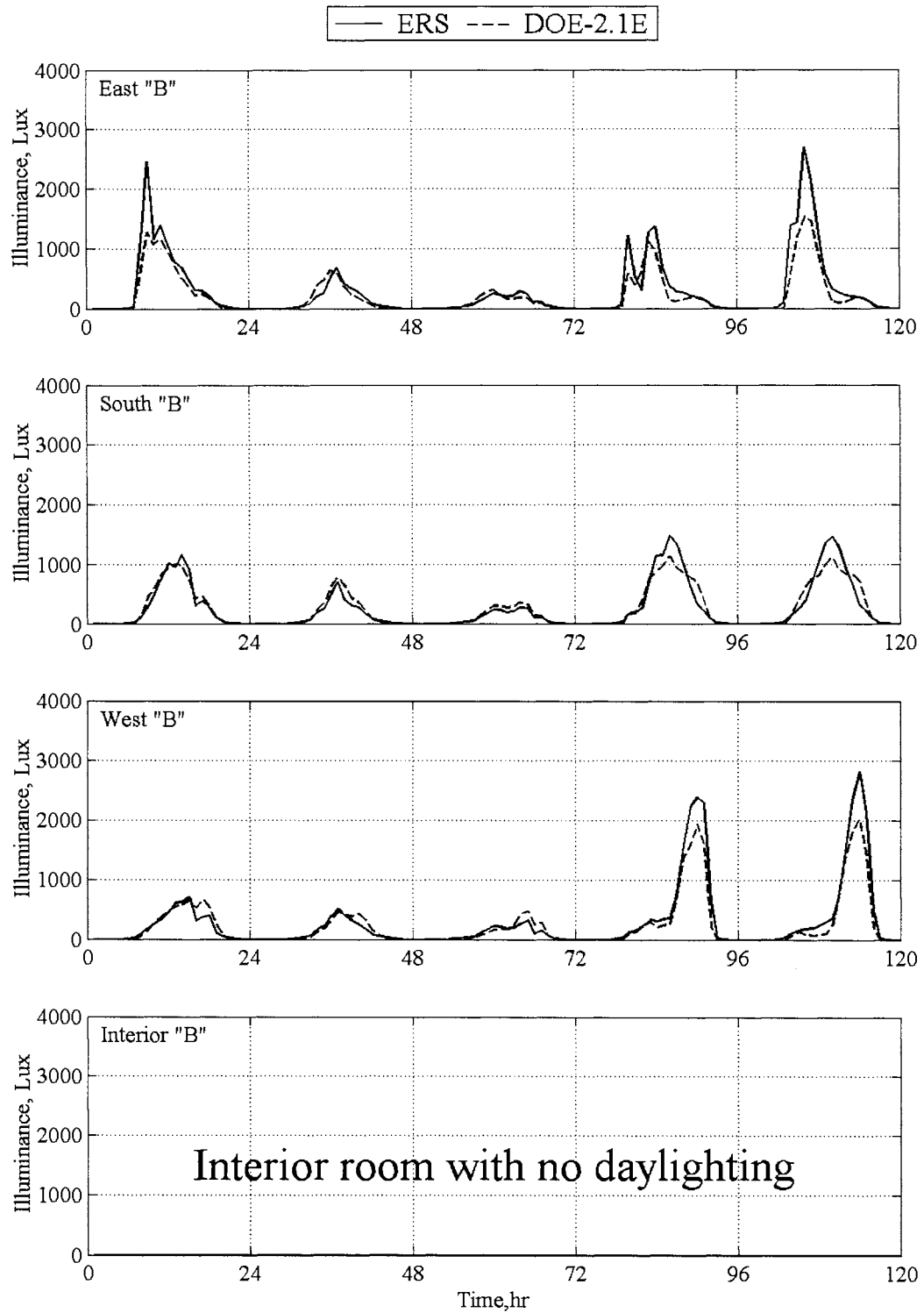


Figure 5.1.3: Illuminance comparisons at the reference point for the "B" rooms Case I.

The illuminance for the exterior “B” systems closely correlated to the values for the “A” exterior test rooms. For these the daylight tests, the illuminance for the “B” system were more important because of the lighting control strategy implemented for the system. The east and west test rooms under-predicted the illuminance when direct sunlight entered the space. This inconsistency had very little impact with regard to predicting the power to the lights, because the lights were dimmed to maintain 645.8 Lux at the reference point. When the illuminance from the ambient light exceeded this set point, the lights were completely turned off. When large discrepancies occurred in the predicted illuminance versus the measured illuminance from the experiment, the lights were turned off for both cases. A statistical comparison for the illuminance for “B” test room Case I is shown in Table 5.1.2.

Table 5.1.2: Statistical comparisons for the illuminance for the “B” rooms Case I, in Lux.

Statistics	East “B”		South “B”		West “B”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	279.2	206.1	248.0	252.7	275.7	232.8
σ	28.1	NA	27.4	NA	28.7	NA
S	498.7	342.6	384.0	340.8	550.4	425.0
x_{\max}	2692.0	1528.9	1483.0	1137.0	2833.0	2035.1
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
\bar{D}	NA	73.1	NA	-4.8	NA	42.9
D_{\max}	NA	1181.3	NA	409.1	NA	797.9
D_{\min}	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	92.7	NA	65.4	NA	77.3
D_{rms}	NA	214.2	NA	119.0	NA	168.1
SE	NA	35.5	NA	-1.9	NA	18.5
IE	NA	45.0	NA	25.9	NA	33.2

Comparisons for the East “B” test room closely matched the comparisons calculated for the East “A” test room. The predicted values for the “B” test room were better than those for the calculated for the “A” test rooms. Small experimental precision error may have contributed to the discrepancy. On the whole, the simulation error was less than 1% greater than the experiment. There was significantly greater error seen in the instantaneous error, which indicated some discrepancies in the hour-by-hour predictions.

Like the other “B” exterior test rooms, the errors were not quite as large as the “A” exterior test rooms. The larger errors in the predicted illuminance versus the experimental illuminance had very little impact on the predicted light power. Like the “A” test rooms, all

the calculated averages differences for the illuminance exceeded their 95% uncertainty bounds.

Zone Light Power

Zone light power was measured during the experiment and compared with predicted results from DOE-2.1E. The “A” test rooms were configured to run at maximum capacity when the lights were scheduled on. The light power results for the “A” test rooms for Case I are shown in Figure 5.1.4.

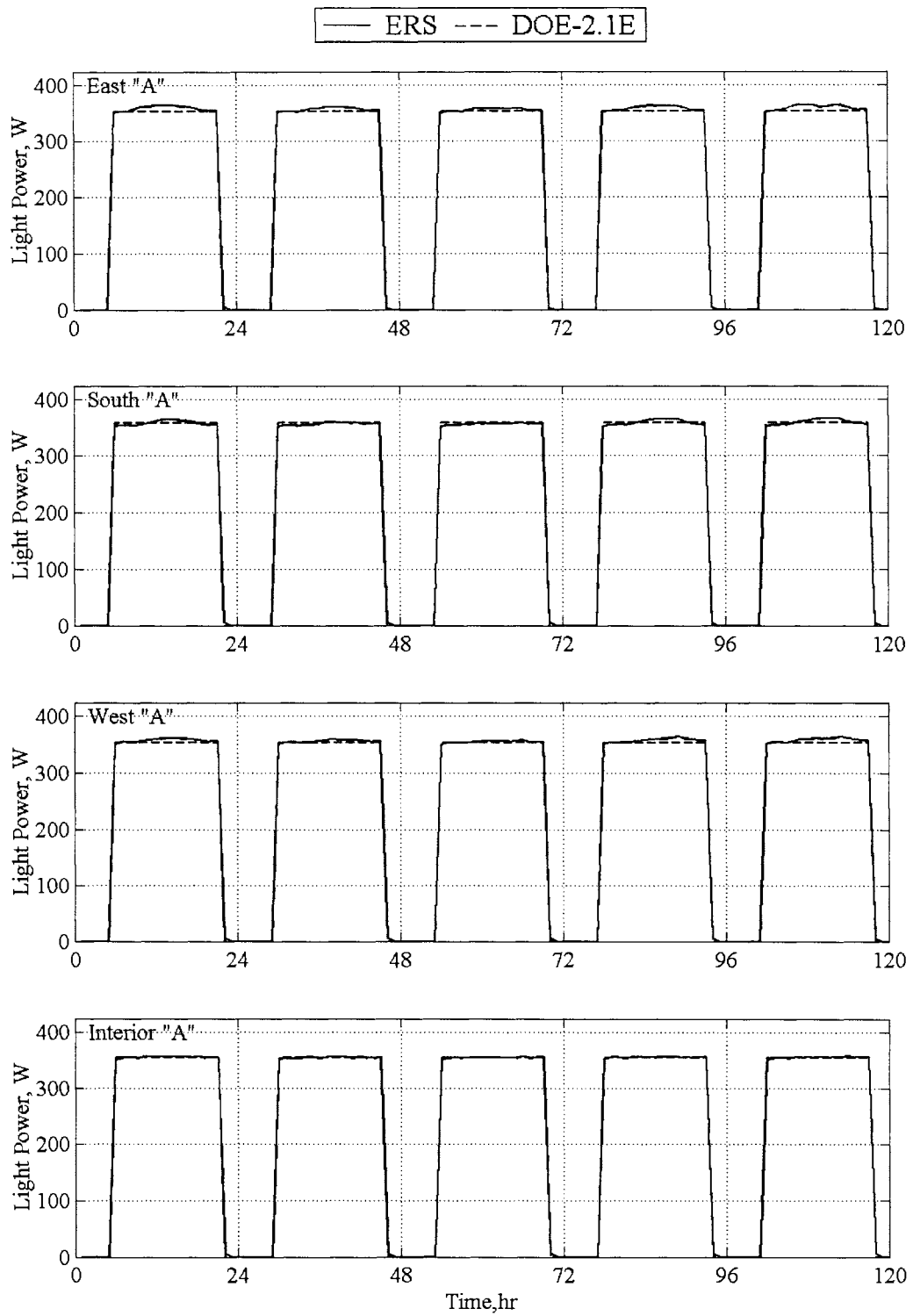


Figure 5.1.4: Light power comparisons for the "A" rooms Case I.

The light power and schedule was a user input rather than a DOE-2.1E validation parameter. Therefore the plots in Figure 5.1.4 verify that the light power and schedule were entered into the simulation correctly; therefore, statistical comparisons were not performed.

Dimmable ballasts were enabled on the “B” exterior test rooms. Both the DOE-2.1E simulation and the experiment varied the light power, which was a function of the illuminance, to maintain a fixed light level at the reference point. These results are shown in Figure 5.1.4.

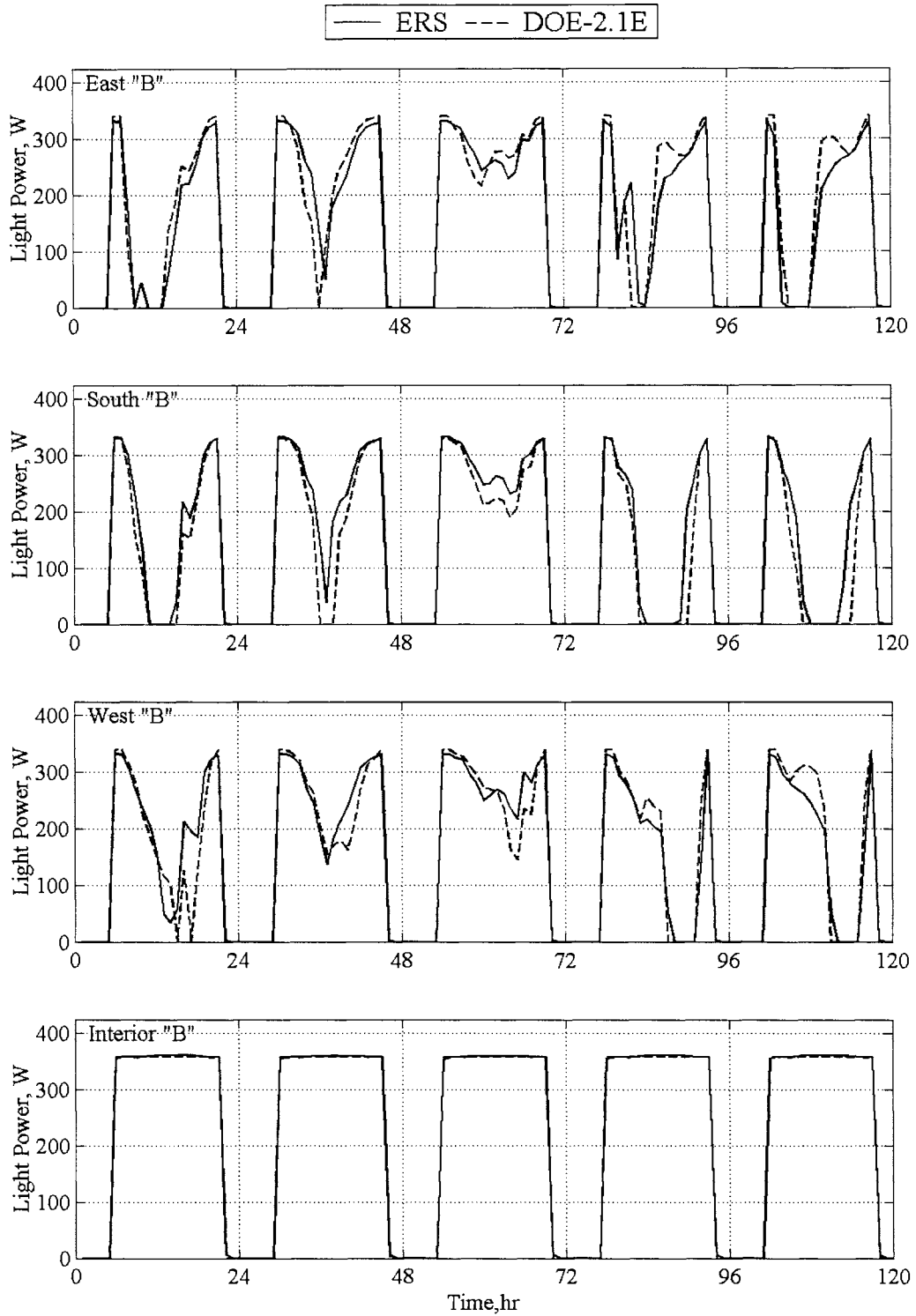


Figure 5.1.5: Light power comparisons for the "B" rooms Case I.

The light power corresponded directly to the measured illuminance at the reference point for the exterior test rooms. On relatively sunny days, despite inconsistencies in the lower

illuminance predictions, the lights were turned off for both the experiment and the DOE-2.1E simulation. Better comparisons were made using statistical parameters. Table 5.1.3 contains the light power comparisons for the “B” test rooms Case I.

Table 5.1.3: Statistical comparisons for light power in the “B” rooms Case I, in W.

Statistics	East “B”		South “B”		West “B”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	147.7	152.8	141.0	122.3	152.5	151.4
σ	0.3	NA	0.3	NA	0.4	NA
S	139.6	146.0	142.6	139.4	138.7	142.6
x_{\max}	333.0	341.1	334.0	329.6	333.0	339.3
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
\bar{D}	NA	-5.2	NA	18.7	NA	1.1
D_{\max}	NA	221.0	NA	212.0	NA	195.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	19.0	NA	18.8	NA	18.4
D_{rms}	NA	37.3	NA	42.1	NA	34.7
SE	NA	-3.4	NA	15.3	NA	0.7
IE	NA	12.5	NA	15.4	NA	12.2

For the east test room, the comparative statistics indicated that DOE-2.1E predicted more light power to the space than what actually occurred. For a summary calculation, the simulation error was relatively small, less the 5%, whereas, for an hour-by-hour comparison, the simulation was not quite as accurate.

For the south test room, the instantaneous error (hour-by-hour calculation) and the summary error were about 15%, which indicates that the simulation consistently under-predicted the light power to the space on an hour-by-hour basis.

For the west test room, the simulation error was very small less than 1%, which indicates a very good summary prediction. The instantaneous error had a similar magnitude as the rest of the exterior ‘B’ test rooms. All the calculated exterior test rooms average differences exceeded their 95% uncertainty bounds. No statistical comparisons were made for the interior “B” test room, because there was no change in the reference point illuminance due to daylighting.

Zone Airflow Rate

The airflow rates for the “A” test rooms are shown in Figure 5.1.6. Cooling was generally required during the day because lights and baseboard heaters transferred heat to the space.

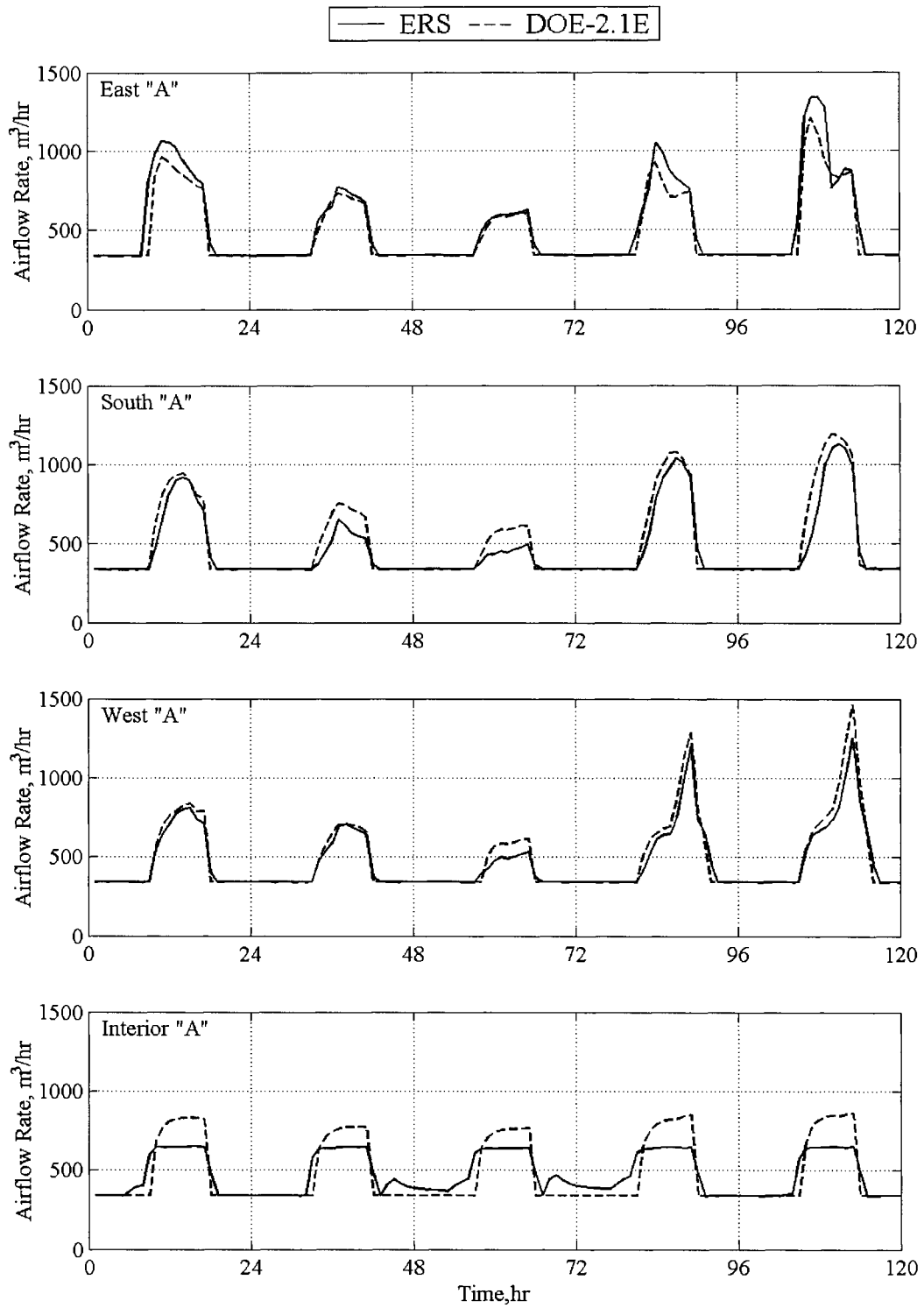


Figure 5.1.6: Zone airflow rates for the "A" rooms Case I.

The airflow rates varied during the day due to loads from the lights, baseboard heaters, solar gain, and envelop load. During the night, the airflow rates for the exterior test rooms remained at the minimum airflow rate set point. There were some discrepancies in the interior test room. The valve on the hydronic coil was unresponsive for parts of the test. For brief periods, it remained open when the building control signaled that it should have been closed. Therefore given the supply fan static pressure set point, the system could not provide the volume of air required to keep the interior room under control; thus the cooling load could not be overcome during the day. Comparative statistics for the airflow rates in the “A” test rooms are shown in Table 5.1.4.

Table 5.1.4: Statistical comparison for the airflow rates for the “A” rooms Case I, in m³/hr.

Statistics	East “A”		South “A”		West “A”		Interior “A”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	510.8	479.3	460.7	492.0	465.8	484.0	473.8	487.6
σ	16.2	NA	15.2	NA	15.3	NA	15.4	NA
s	258.7	220.2	215.4	250.0	195.4	231.4	132.7	212.6
x_{\max}	1335.0	1208.0	1130.0	1195.0	1254.0	1476.0	652.0	871.0
x_{\min}	338.0	340.0	337.0	340.0	339.0	340.0	339.0	340.0
\bar{D}	NA	31.5	NA	-31.4	NA	-18.2	NA	-13.8
D_{\max}	NA	453.0	NA	300.0	NA	222.0	NA	270.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	35.9	NA	38.6	NA	26.7	NA	79.7
D_{rms}	NA	79.4	NA	72.6	NA	52.3	NA	111.6
SE	NA	6.6	NA	-6.4	NA	-3.8	NA	-2.8
IE	NA	7.5	NA	7.8	NA	5.5	NA	16.3

For the airflow rates, the DOE-2.1E simulation consistently over-predicted the zone airflow rates. For the exterior test rooms, the instantaneous error was about the same. Because the interior test room was not in control during the entire test, general comparisons were difficult. For Case II, the supply fan static pressure set point was raised to keep the interior room under control and a hot water valve was fixed.

Zone airflow rates were also simulated for the “B” test rooms. The dimming of the lights in the test room reduced the overall cooling load compared with the “A” systems. All the calculated average airflow differences were within their 95% uncertainty bounds except for the west test room. The airflow rates for the “B” test rooms are shown in Figure 5.1.7.

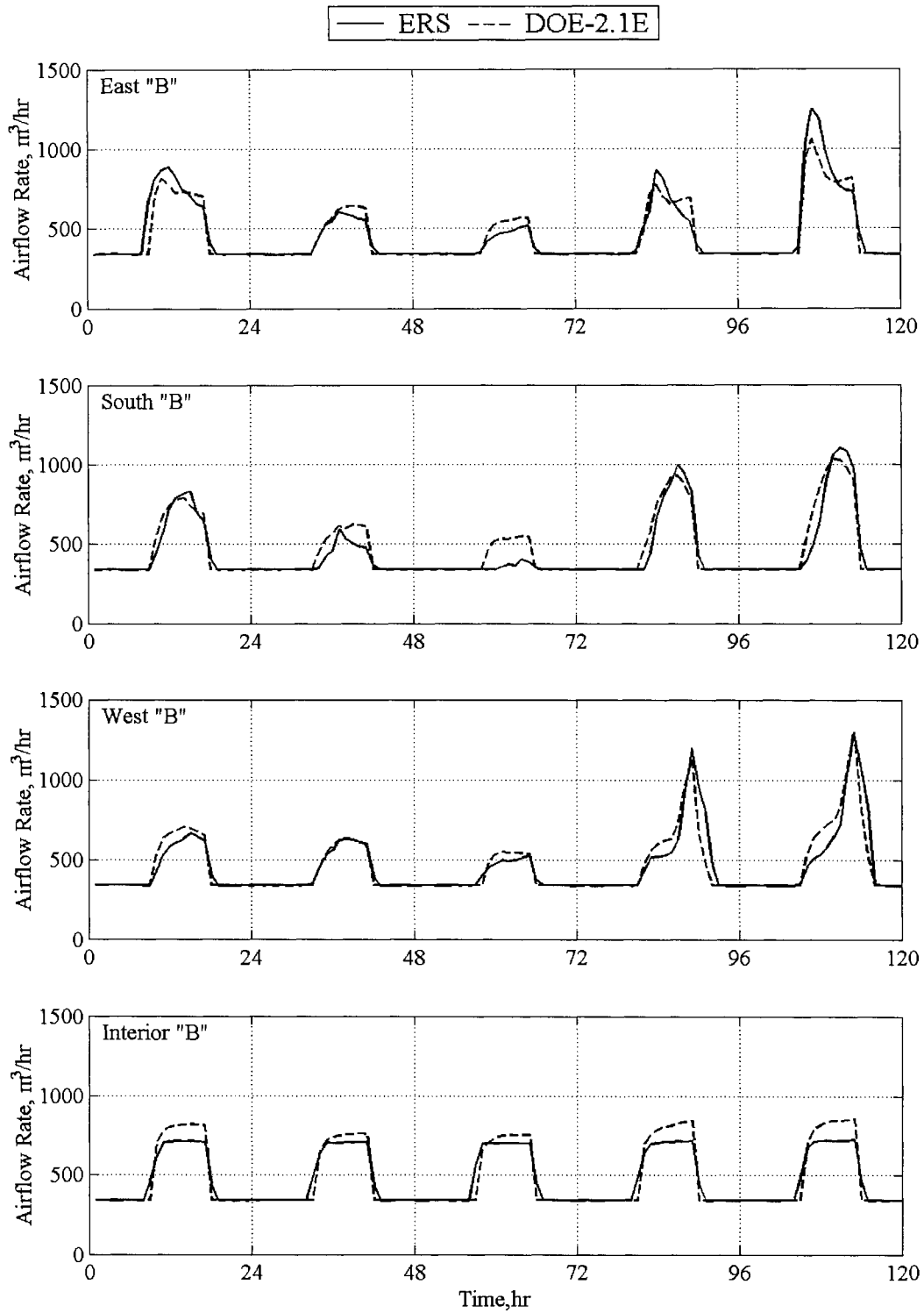


Figure 5.1.7: Zone airflow rates for the "B" rooms Case I.

From Figure 5.1.7, the predicted airflow rates from the DOE-2.1E simulation compare well with experiment. For the interior test room, there was a significant error in the

maximum airflow rate to the space, although it appears that the cooling load was met because the damper went to minimum position at night. The statistical comparisons for the airflow rates from the “B” test rooms are shown in Table 5.1.5.

Table 5.1.5: Statistical comparison for the airflow rates for the “B” rooms Case I, in m³/hr.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	456.9	450.0	435.9	454.2	451.4	458.9	471.8	494.4
σ	14.8	NA	14.2	NA	14.9	NA	14.4	NA
s	196.0	177.3	191.9	191.5	188.3	188.1	168.7	220.8
x_{\max}	1246.0	1056.0	1101.0	1033.0	1287.0	1277.0	728.0	876.0
x_{\min}	335.0	340.0	338.0	340.0	339.0	340.0	339.0	340.0
\bar{D}	NA	6.9	NA	-18.2	NA	-7.6	NA	-22.6
D_{\max}	NA	333.0	NA	216.0	NA	388.0	NA	221.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	30.2	NA	34.7	NA	37.9	NA	44.5
D_{rms}	NA	60.7	NA	65.1	NA	79.9	NA	72.0
SE	NA	1.5	NA	-4.0	NA	-1.6	NA	-4.6
IE	NA	6.7	NA	7.6	NA	8.3	NA	9.0

The summary error for the east and west test rooms was relatively small, whereas the south test room over-predicted the airflow rate. The instantaneous error was about the same for all the test rooms. Comparable results were seen in the interior test room, which seems odd because the interior test room was not exposed to factors like solar gain, infiltration, or conduction through exterior surfaces. The east and west test rooms’ mean airflow average differences were within their 95% uncertainty bounds, whereas the south and interior test rooms were not.

Zone Reheat Power

Zone heat was provided to the test rooms from hydronic coils in the zone VAV box. The heating coils were activated when the zone temperature of the room fell below the heating set point temperature. There was no direct measurement for the reheat power to the space, so the heat transfer rate to the air was calculated using the energy balance in Equation 5.1.1.

$$q_{zone} = \frac{pQ_{zone}}{RT_{EAT}} c_p (T_{DAT} - T_{EAT}) \quad (5.1.1)$$

where

p is the measure ambient pressure.

Q_{zone} is room airflow rate.

R is the gas constant for air.

T_{EAT} is the entering air temperature.

T_{DAT} is the discharge air temperature.

The following assumptions were made for this calculation:

- Steady state.
- Dry air.
- Ideal gas.
- System pressure was negligible.
- Constant specific heat for air at 27 °C.

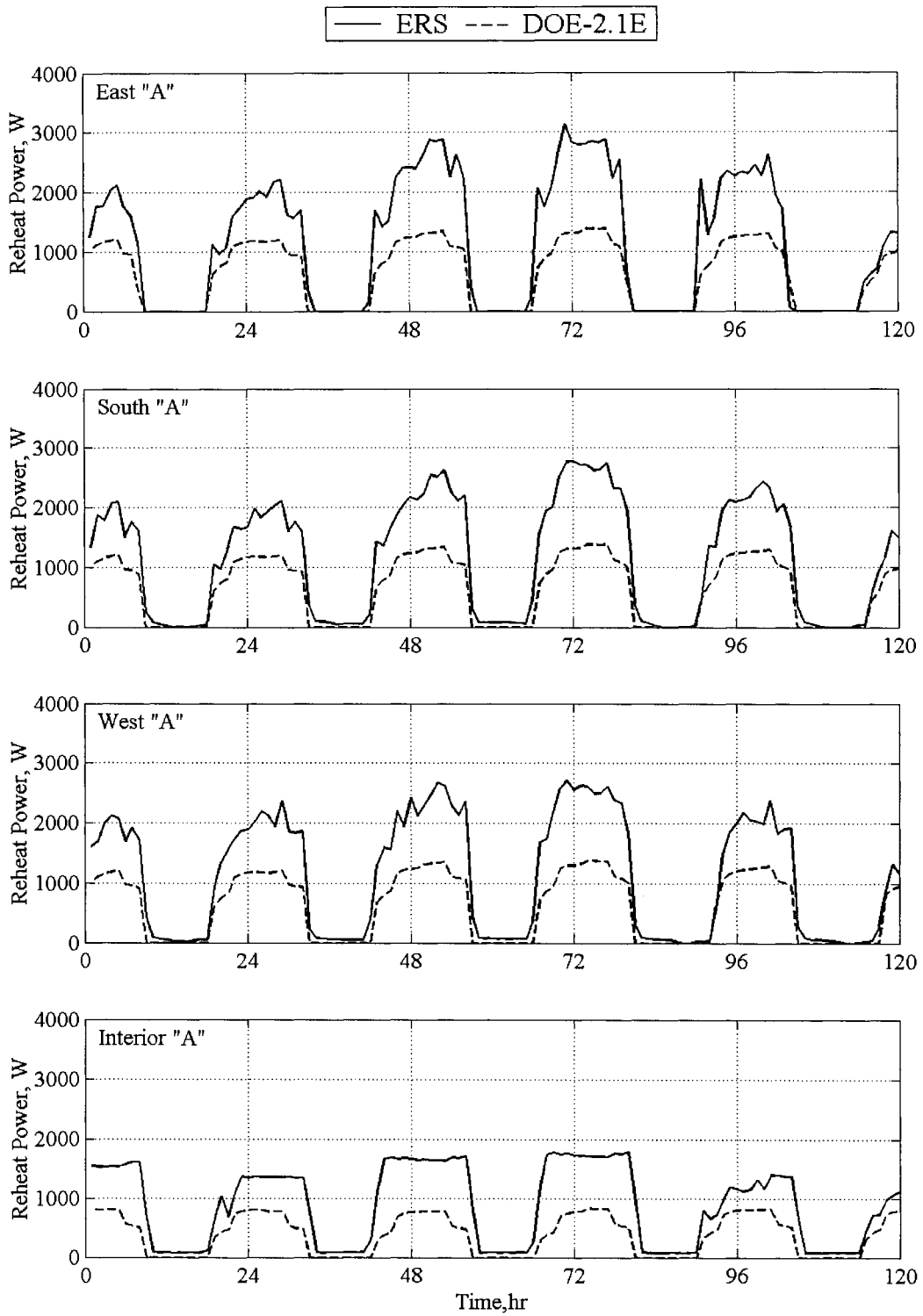


Figure 5.1.8: Reheat power for the "A" rooms Case I.

Large discrepancies can be seen from the reheat plots. The apparent magnitude of these discrepancies can be more accurately quantified by the statistical comparisons shown in Table 5.1.6.

Table 5.1.6: Statistical comparison for the reheat power for the “A” rooms Case I, in W.

Statistics	East “A”		South “A”		West “A”		Interior “A”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	1002.9	612.6	1133.2	617.1	1115.4	599.4	876.4	379.7
σ	217.9	NA	200.2	NA	202.2	NA	187.4	NA
s	946.0	557.7	988.9	559.7	1007.6	572.0	678.0	348.3
x_{\max}	2747.0	1368.0	2771.0	1368.0	2711.0	1386.0	1800.0	815.0
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0	70.0	0.0
\bar{D}	NA	390.4	NA	516.1	NA	516.0	NA	496.8
D_{\max}	NA	1414.0	NA	1434.0	NA	1378.0	NA	1330.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	70.0
$ D $	NA	396.2	NA	516.1	NA	517.6	NA	496.8
D_{rms}	NA	577.8	NA	684.3	NA	689.2	NA	638.1
SE	NA	63.7	NA	83.6	NA	86.1	NA	130.8
IE	NA	64.7	NA	83.6	NA	86.4	NA	130.8

The large discrepancies were assumed to be from zone stratification. This was later verified in an experiment described in a subsequent section. The stratification problem led to large error for the exterior test rooms of between 60% and 80%. These simulation and the instantaneous errors were about the same magnitude, which indicated under prediction throughout the entire test. The interior room experienced even greater errors. When comparing the average airflow rate differences between the experiment and the predicted quantity of DOE-2.1E, there was a discrepancy of between 400 to 500 m³/hr. This kind of error corresponds to either a large simulation error or an improperly configured test zone. None of the reheat power average differences were even close to their 95% uncertainty bounds.

The results for the reheat power for the “B” test rooms are shown in Figure 5.1.9.

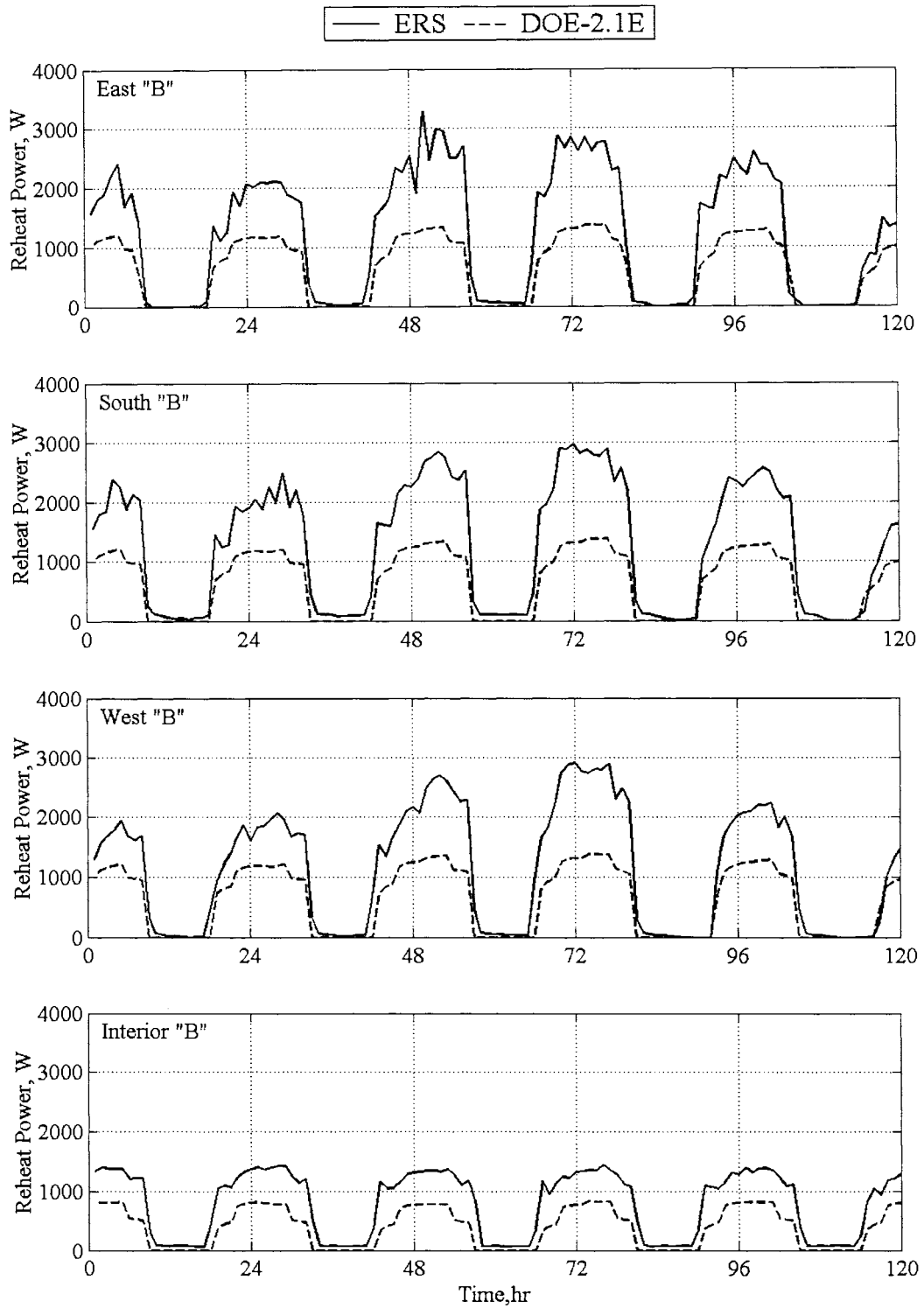


Figure 5.1.9: Reheat power for the "B" rooms Case I.

Large errors were also seen from in the “B” test rooms. There were also large discrepancies between the interior test rooms. This may have been due to the unresponsive heating valve for the “A” test room. The statistical comparisons for the “B” test rooms can be found in Table 5.1.7.

Table 5.1.7: Statistical comparison for the reheat power for the “B” rooms Case I, in W.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	1210.6	623.2	1267.1	632.7	1118.5	610.5	782.1	383.4
σ	201.8	NA	197.3	NA	197.4	NA	187.4	NA
S	1072.9	558.8	1068.3	561.6	1015.8	573.0	562.0	349.8
x_{\max}	3286.0	1368.0	2969.0	1368.0	2909.0	1387.0	1439.0	815.0
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.0
\bar{D}	NA	587.4	NA	634.4	NA	508.1	NA	398.6
D_{\max}	NA	1962.0	NA	1631.0	NA	1572.0	NA	844.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	60.0
$ D $	NA	594.8	NA	638.9	NA	511.5	NA	398.6
D_{rms}	NA	799.4	NA	824.7	NA	699.3	NA	469.6
SE	NA	94.3	NA	100.3	NA	83.2	NA	104.0
IE	NA	95.5	NA	101.0	NA	83.8	NA	104.0

Simulation and instantaneous errors comparable to those for the “A” test room were seen for the “B” test rooms. During the night, the rooms were “identical” with regard to the thermal loads. Like for the “A” test rooms, none of the reheat power average differences were even close to their 95% uncertainty bounds.

Zone Temperature

The zone temperatures for both the “A” and the “B” test rooms were measured and predicted by the DOE-2.1E. There was a 0.6°C dead band between when the system was cooling and heating, which corresponded to 22.2°C and 22.8°C, respectively. When the zone temperature was between the set points, the airflow rate was at the minimum position but the hydronic heating coils were not engaged. The graphical results for the zone temperatures in the “A” test rooms are shown in Figure 5.1.10.

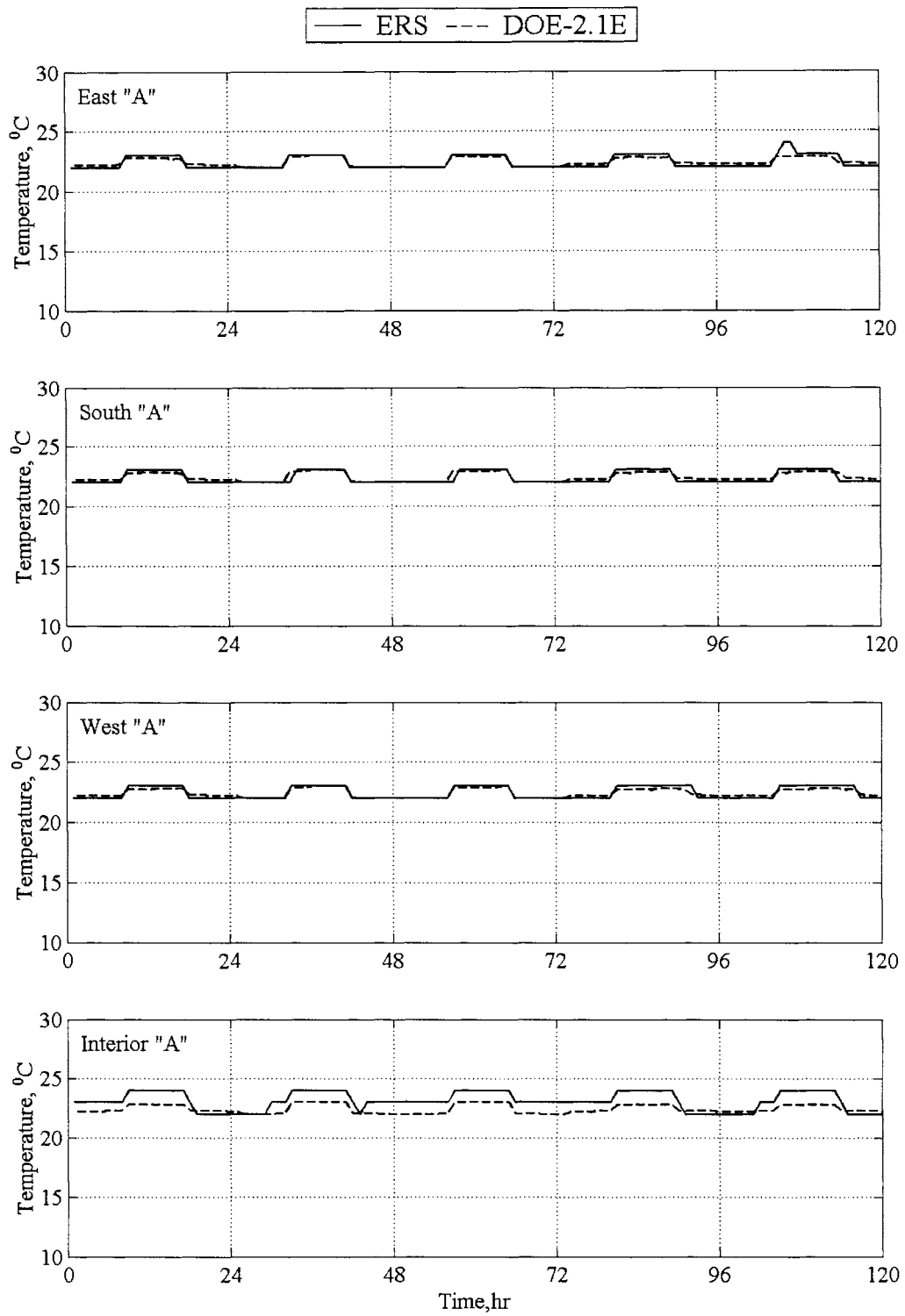


Figure 5.1.10: Zone temperature for the "A" rooms Case I.

The plots show that for a brief period the east test room was not under control. During the entire test, the interior test room was not under control. This was evident because the zone temperature exceeded the cooling set point temperature. Similar indications were also apparent from the zone airflow rate plots shown in Figure 5.1.6. Statistical comparisons for the zone temperatures for the “B” test rooms are shown in Table 5.1.8.

Table 5.1.8: Statistical comparisons of zone temperatures for the “A” rooms Case I in °C.

Statistics	East “A”		South “A”		West “A”		Interior “A”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	22.4	22.4	22.4	22.4	22.4	22.4	23.1	22.4
σ	0.2	NA	0.2	NA	0.2	NA	0.2	NA
S	0.5	0.4	0.5	0.4	0.5	0.4	0.8	0.4
x_{\max}	24.0	23.0	23.0	23.0	23.0	23.0	24.0	23.0
x_{\min}	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
\bar{D}	NA	0.0	NA	0.0	NA	0.0	NA	0.7
D_{\max}	NA	1.2	NA	0.9	NA	0.7	NA	1.2
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	0.2	NA	0.2	NA	0.2	NA	0.8
D_{rms}	NA	0.2	NA	0.2	NA	0.2	NA	0.9
SE	NA	0.0	NA	-0.2	NA	0.1	NA	3.1
IE	NA	0.8	NA	0.7	NA	0.7	NA	3.6

In general, reasonable results between the experiment and the DOE-2.1 predictions were seen. The large variations occurred in the interior test room where the maximum capacity of the system was unable to supply the required volume of air to maintain control of the interior test room. There were several hours in the DOE-2.1E simulation where the temperature was between the dead band which may have indicated brief periods in the simulation where the cooling at the minimum airflow was enough to maintain the space conditions. The average zone temperature difference for the interior test room exceeded its 95% uncertainty bounds, because it was not under control. Because the zone temperature was a control point, very good comparisons for the average zone temperature difference were seen for the exterior test rooms with respect to their 95% uncertainty bounds.

Comparisons for the zone temperatures of the “B” test rooms were also made. The graphical results are shown in Figure 5.1.11.

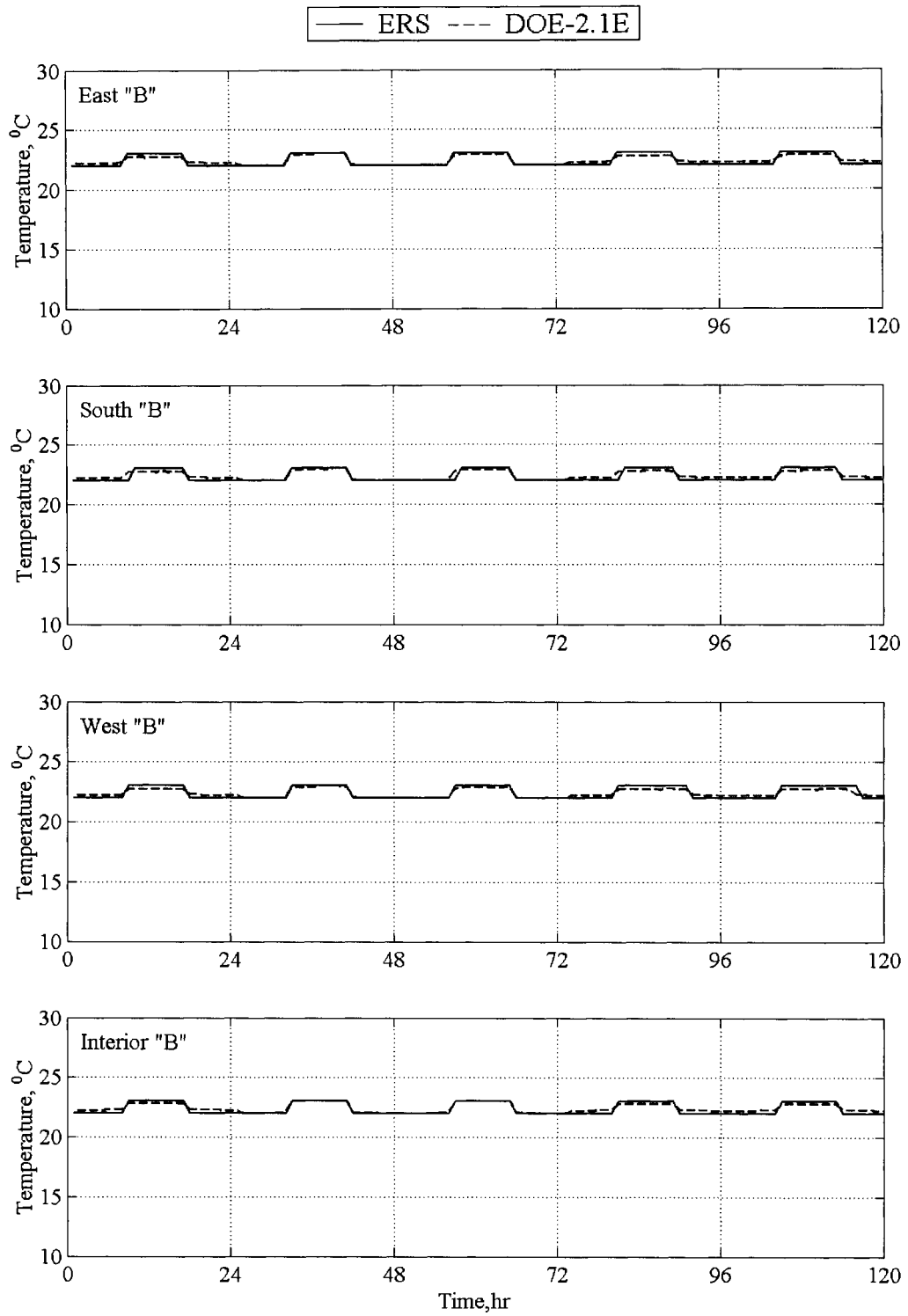


Figure 5.1.11: Zone air temperatures for the "B" rooms Case I.

The statistical comparisons for the zone temperatures in the “B” test rooms are shown in Table 5.1.9.

Table 5.1.9: Statistical comparisons for zone temperatures for the “B” rooms Case I, in °C.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
σ	0.2	NA	0.2	NA	0.2	NA	0.2	NA
S	0.5	0.3	0.5	0.3	0.5	0.3	0.5	0.4
x_{\max}	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
x_{\min}	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
\bar{D}	NA	0.0	NA	0.0	NA	0.0	NA	-0.1
D_{\max}	NA	0.3	NA	0.8	NA	0.7	NA	0.3
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	0.2	NA	0.2	NA	0.2	NA	0.2
D_{rms}	NA	0.2	NA	0.2	NA	0.2	NA	0.2
SE	NA	-0.1	NA	-0.2	NA	0.1	NA	-0.3
IE	NA	0.7	NA	0.7	NA	0.7	NA	0.7

The test rooms operated in the same manner but, unlike the “A” systems, all room remained under control during the test. The simulation and instantaneous errors for all the test rooms were approximately the same and negligible.

System Comparisons

System parameters from the experiment were compared with the DOE-2.1E simulation predictions. The following system parameters were compared:

- Supply airflow rates.
- Return air temperatures.
- Leaving coil air temperatures.
- Cooling heat transfer rates.

A brief description of each quantity and graphical and statistical parameters are provided in this section.

Supply Airflow Rate

The supply airflow rate was the sum of the room airflow rates for the respective systems. The values closely corresponded to the return airflow rate because the systems were configured to use 100% re-circulated air.

Return Air Temperature

The return air temperature was the temperature measured in the return air duct. This generally corresponded well with the room air temperatures.

Leaving Coil Temperature

The leaving coil temperature was measured by a RTD array and the value reported by the building control system was the arithmetic average of the temperatures. This was done to account for changes in the temperature due to the turbulent thermal boundary layer as well as buoyancy effects within a larger duct. The temperature was taken prior to the supply fan and was lower than the controlled supply air temperature.

Cooling Heat Transfer Rate

The cooling heat transfer rate was a calculation of the amount of energy removed from the air stream by the cooling coils. No direct measurement for the cooling heat transfer rate is possible; therefore, an air energy balance was used to calculate the heat transfer rate shown in equation 5.1.2.

$$q_{cooling} = \frac{pQ_{SYSTEM}}{RT_{MA}} c_p (T_{MA} - T_{LC}) \quad (5.1.2)$$

where

p is the ambient pressure.

Q_{ROOM} is the system airflow rate.

R is the gas constant for air.

c_p is the constant specific heat for air at 27 °C.

T_{MA} is the mixed air temperature.

T_{LC} is the leaving cooling coil air temperature.

The following assumptions were made for this calculation:

- Steady state.
- Dry air.
- Ideal gas.
- System pressure was negligible.
- Constant specific heat at 27 °C.

System Results

The graphical results for the “A” system are shown in Figure 5.1.12 for the experiment and the DOE-2.1E simulation.

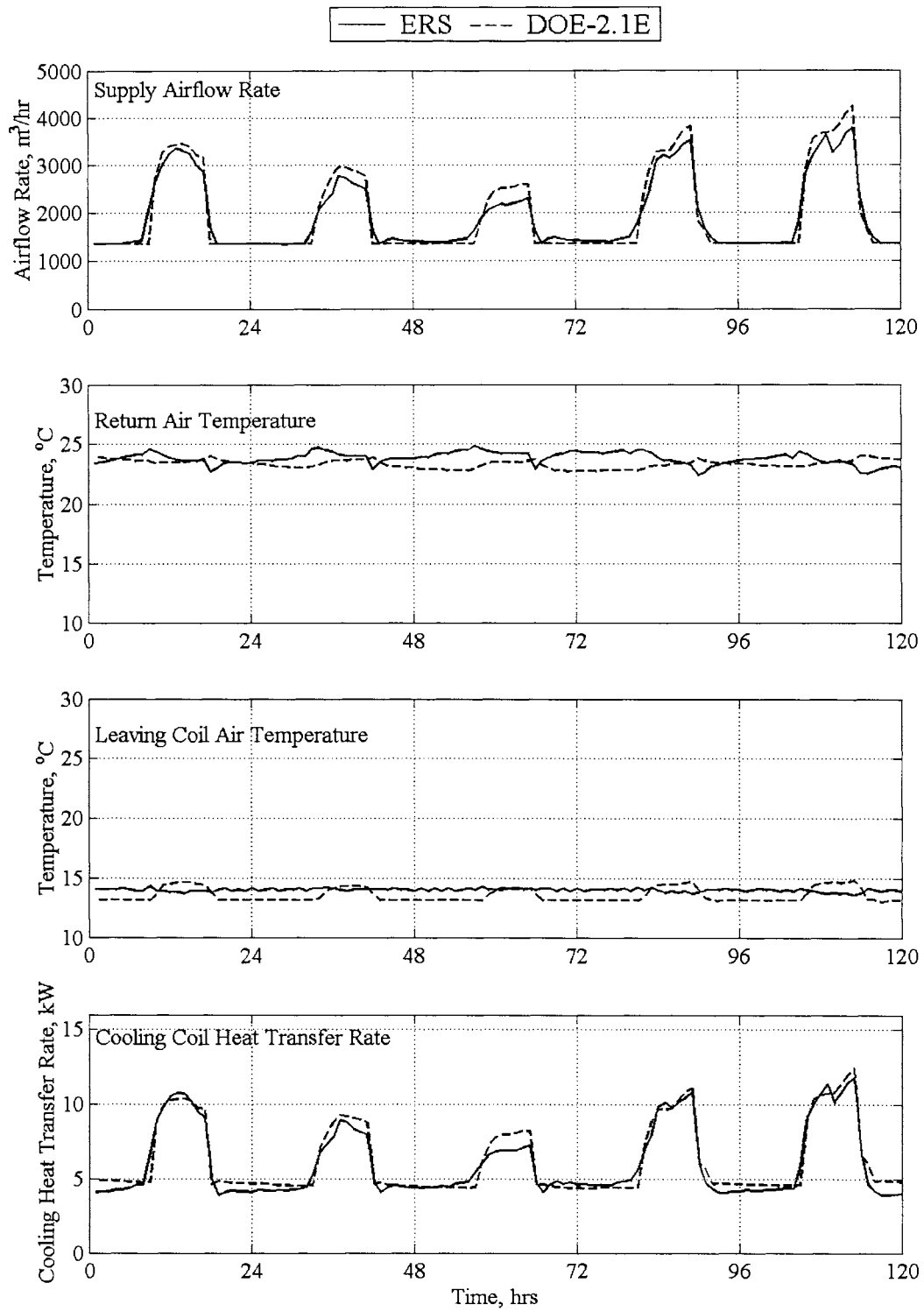


Figure 5.1.12: System “A” parameters for Case I.

As seen from the plots, the simulation did a fair job of predicting the system parameters. Perhaps more indicative were the statistical comparisons for the “A” system shown in Table 5.1.10.

Table 5.1.10: Statistical comparison for the “A” system Case I.

Statistics	Supply Airflow Rate, m ³ /hr		Return Air Temp, °C		Leaving Coil Temp, °C		Cooling HTR, KW	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	1911.1	1944.0	23.8	23.3	14.0	13.5	6.0	6.2
σ	31.6	NA	0.2	NA	0.2	NA	0.8	NA
S	732.3	866.2	0.5	0.3	0.1	0.6	2.4	2.4
x_{\max}	3773.0	4252.0	24.8	24.0	14.3	14.8	11.8	12.5
x_{\min}	1356.0	1359.0	22.4	22.7	13.6	13.0	3.9	4.4
\bar{D}	NA	-33.0	NA	0.5	NA	0.5	NA	-0.2
D_{\max}	NA	716.0	NA	1.9	NA	1.2	NA	2.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	132.3	NA	0.8	NA	0.8	NA	0.5
D_{rms}	NA	197.5	NA	0.9	NA	0.8	NA	0.6
SE	NA	-1.7	NA	2.1	NA	3.5	NA	-3.7
IE	NA	6.8	NA	3.2	NA	5.6	NA	7.6

The simulations and instantaneous errors were very small for the “A” system. There were some discrepancies in the return air temperature, which may have been due to the room stratification problem during zone heating. Also, the leaving coil temperature varies quite a bit more due to the fan power for the DOE-2.1E simulations compared with what was seen in the experiment. The average cooling heat transfer rate difference was within its 95% uncertainty bounds. The average differences for the supply air temperature, return air temperature, and leaving coiling temperature exceeded their 95% uncertainty bounds.

Graphical comparisons for “B” system were made with the same parameters. The graphical comparisons are shown in Figure 5.1.13.

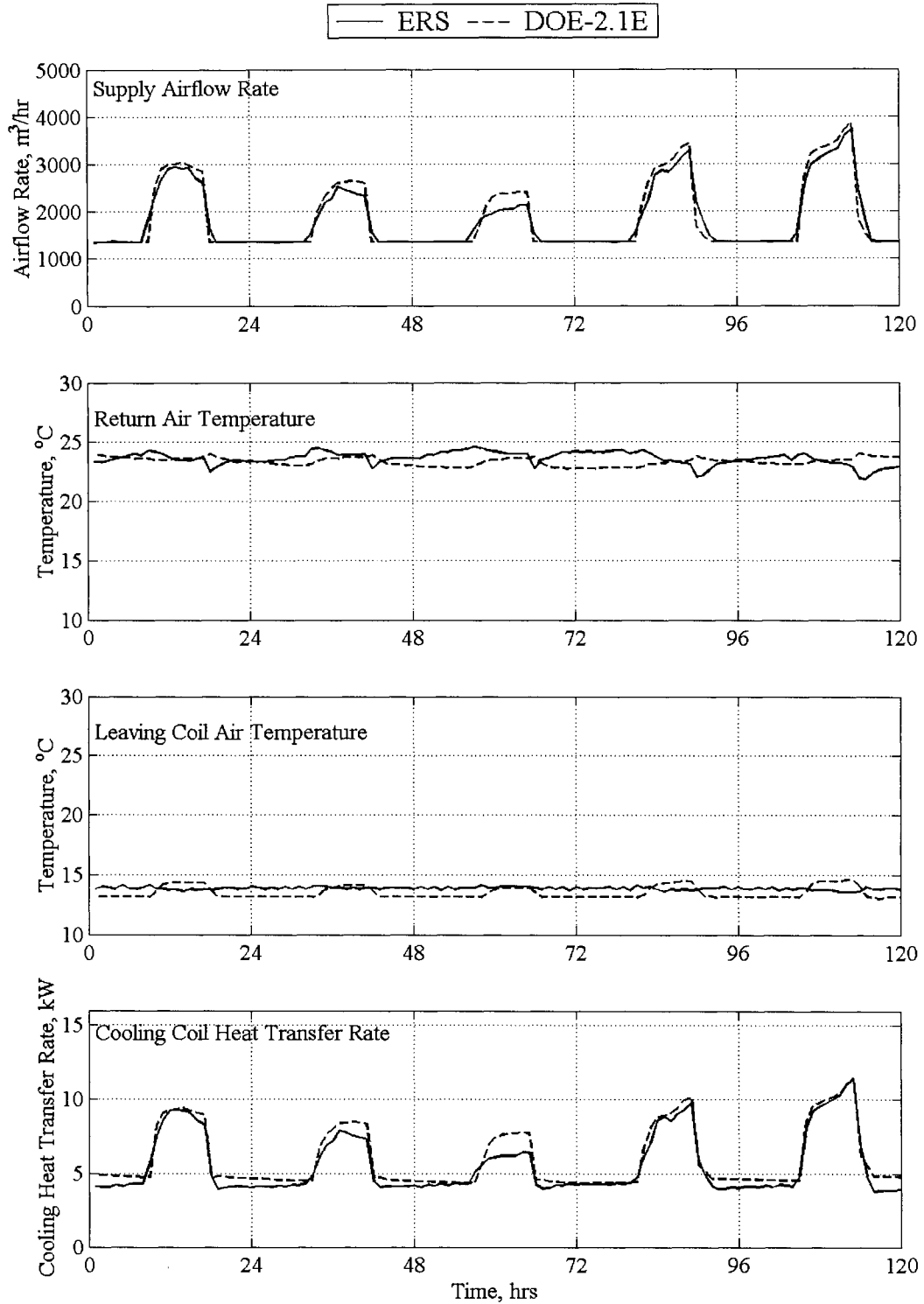


Figure 5.1.13: System "B" parameters for Case I.

The statistical comparisons for the "B" system are shown in Table 5.1.11.

Table 5.1.11: Statistical comparison for the “B” system Case I.

Statistics	Supply Airflow Rate, m ³ /hr		Return Air Temp, °C		Leaving Coil Temp, °C		Cooling HTR, KW	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	1816.1	1847.7	23.6	23.3	13.9	13.5	5.6	6.0
σ	30.0	NA	0.2	NA	0.2	NA	0.8	NA
s	647.5	731.6	0.6	0.3	0.1	0.5	2.0	2.1
x_{\max}	3728.0	3875.0	24.6	24.0	14.1	14.6	11.4	11.5
x_{\min}	1355.0	1359.0	21.8	22.7	13.6	13.0	3.8	4.4
\bar{D}	NA	-31.6	NA	0.3	NA	0.4	NA	-0.4
D_{\max}	NA	625.0	NA	2.1	NA	1.0	NA	1.5
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	99.6	NA	0.7	NA	0.7	NA	0.5
D_{rms}	NA	165.4	NA	0.9	NA	0.7	NA	0.6
SE	NA	-1.7	NA	1.2	NA	3.0	NA	-7.2
IE	NA	5.4	NA	2.9	NA	4.9	NA	8.3

The predicted values for the system “B” DOE-2.1E simulation were comparable to the predicted values for the system “A” predictions. The average cooling heat transfer rate difference was within its 95% uncertainty bounds. The average differences for the supply air temperature, return air temperature, and leaving coiling temperature exceeded their 95% uncertainty bounds.

5.2 Daylight Test Case II

The results from the daylight test performed from January 29 to February 2, 2003 are described in this section.

Weather Comparisons

Figure 4.1.1 provides graphical comparison parameters from the ERS and output parameters from the DOE-2.1E simulation for Case II.

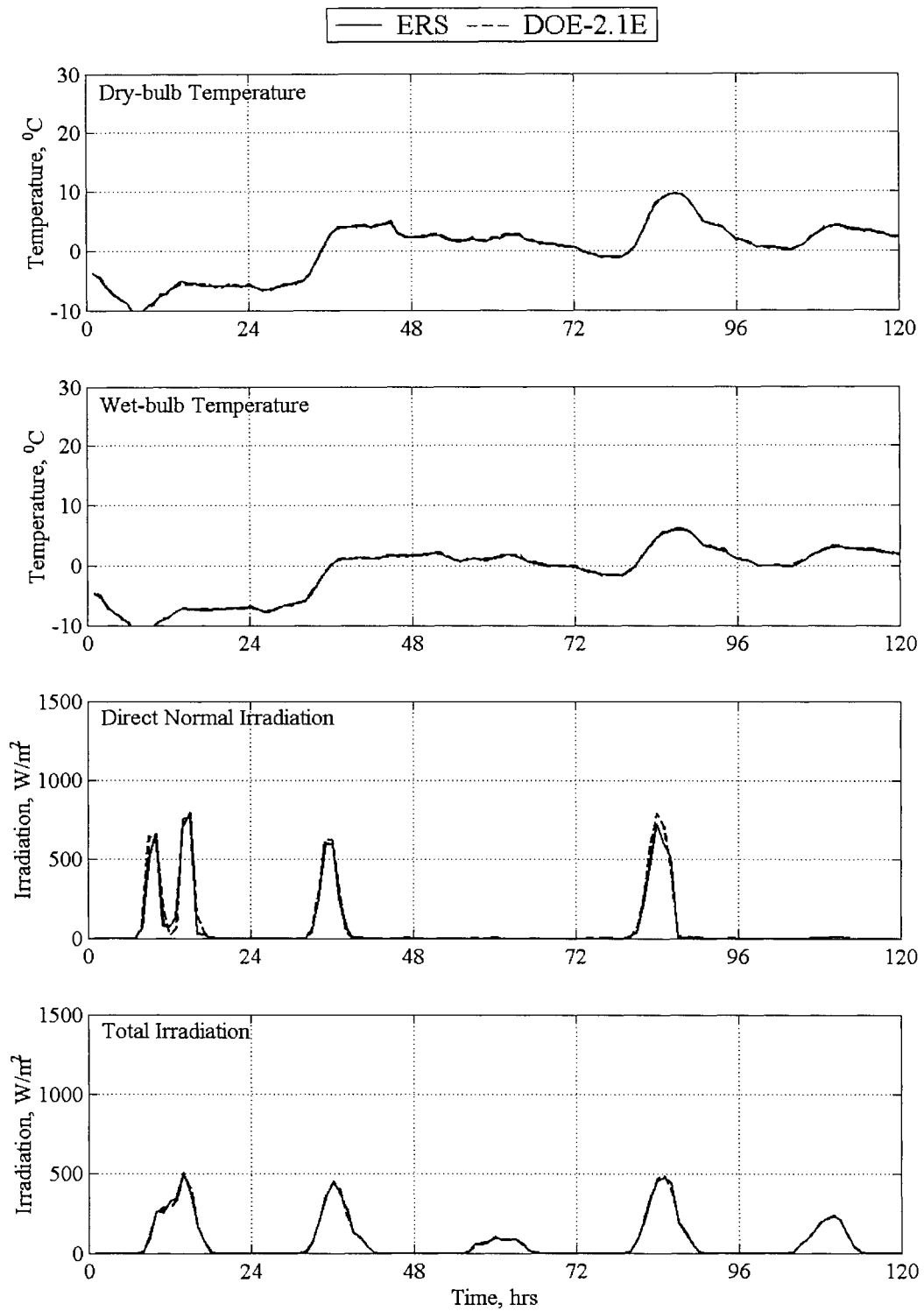


Figure 5.2.1: Simulation and experimental weather comparisons Case II.

For Case II, the direct-normal irradiation measurements in Figure 5.2.1 indicated that the test consisted of relatively cloudy days with a few hours of sun on the first, second, and fourth day. Less dimming would be expected compared with the results from Case I.

Zone Comparisons

Zone comparisons were made for various parameters from the ERS and the DOE-2.1E simulations. The following parameters were compared:

- Zone illuminance at the reference point.
- Zone light power.
- Zone airflow rates.
- Zone reheat power.
- Zone temperature.

These parameters were measured and calculated for both the “A” and the “B” test rooms despite the fact the dimmable ballasts for the lights were only enabled for the “B” test rooms.

Zone Illuminance at the Reference Point

The graphical comparisons for the “A” test rooms for Case II can be found in Figure 5.2.2.

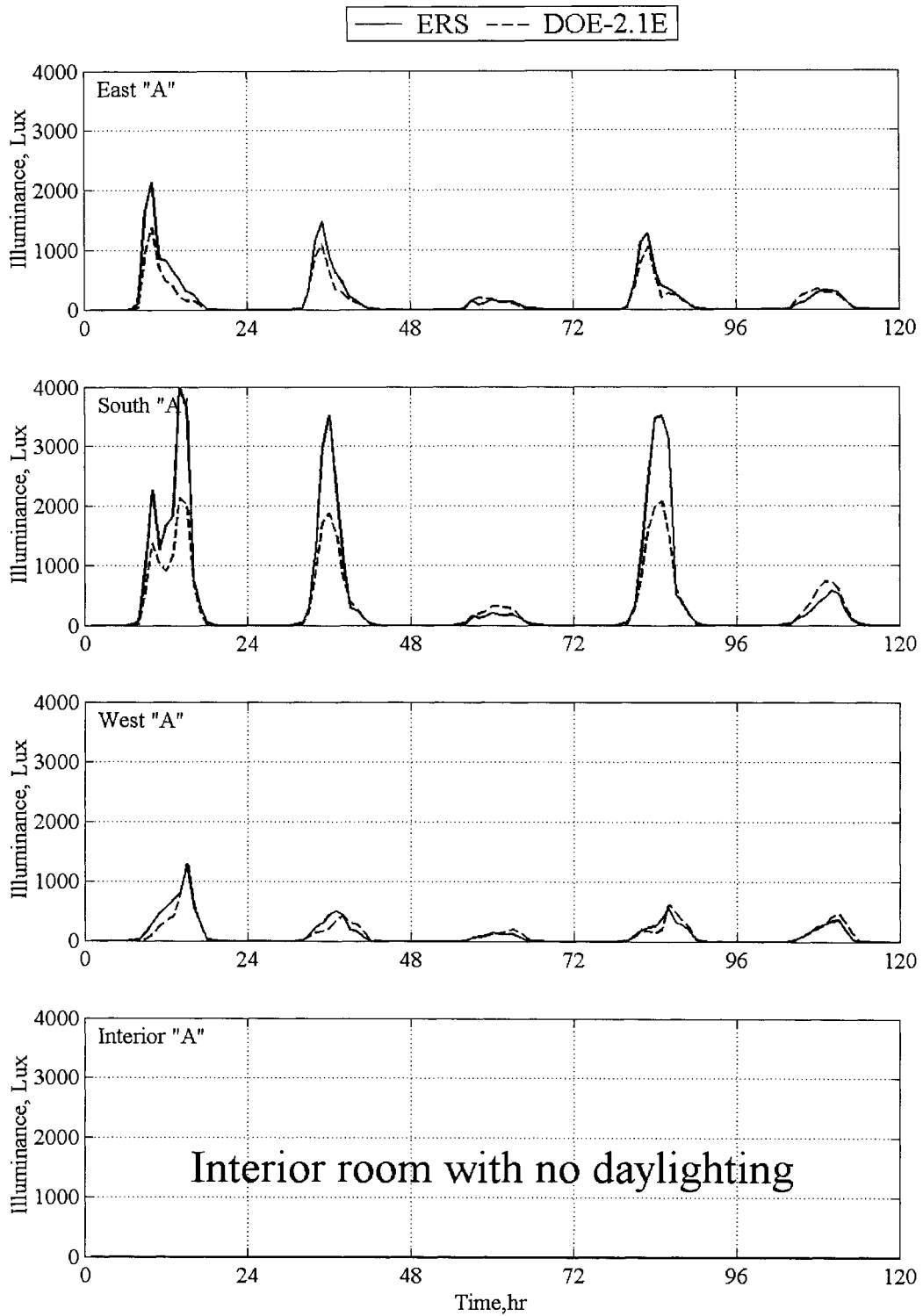


Figure 5.2.2: Illuminance comparisons at the reference point for the "A" rooms Case II.

On cloudy days and in the south test room, the predicted illuminance was consistent with the measured illuminance. This test was performed in the winter when the path of the sun was very shallow. Therefore, the south room was exposed to larger magnitudes of sunlight throughout the day. Table 5.2.1 contains the statistical parameters for the illuminance at the reference points for the “A” test rooms.

Table 5.2.1: Statistical comparisons for the illuminance in the “A” rooms Case II, in Lux.

Statistics	East “A”		South “A”		West “A”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	170.2	128.4	405.6	278.4	106.5	100.1
σ	5.6	NA	8.2	NA	3.8	NA
s	362.3	253.3	902.8	526.5	196.3	189.5
x_{\max}	2139.0	1379.5	3993.0	2130.5	1258.0	1314.5
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
\bar{D}	NA	41.7	NA	127.1	NA	6.4
D_{\max}	NA	759.5	NA	1862.5	NA	272.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	52.8	NA	161.3	NA	32.0
D_{rms}	NA	132.0	NA	420.4	NA	65.8
SE	NA	32.5	NA	45.7	NA	6.4
IE	NA	41.1	NA	57.9	NA	32.0

From Table 5.2.1, the instantaneous errors for both the south and east test rooms were relatively high. The discrepancies for the east test room occurred in the morning when it was exposed to high magnitudes of sunlight. The discrepancies in the south test rooms occurred during most of the day because of the path of the sun. The instantaneous error for the south test room was the largest of all the test rooms. The mean illuminance difference for all the test rooms exceeded the 95% uncertainty bounds.

Smaller simulation and instantaneous errors indicate the predicted values from DOE-2.1E were seen for the west test room. From the measured illuminance in Figure 5.2.2, the west test room was never subjected to large amounts of illuminance.

There was no daylighting in the interior test rooms; therefore no statistical comparisons were performed. Similar comparisons for the illuminance were made for the “B” test rooms Case II shown in Figure 5.2.2.

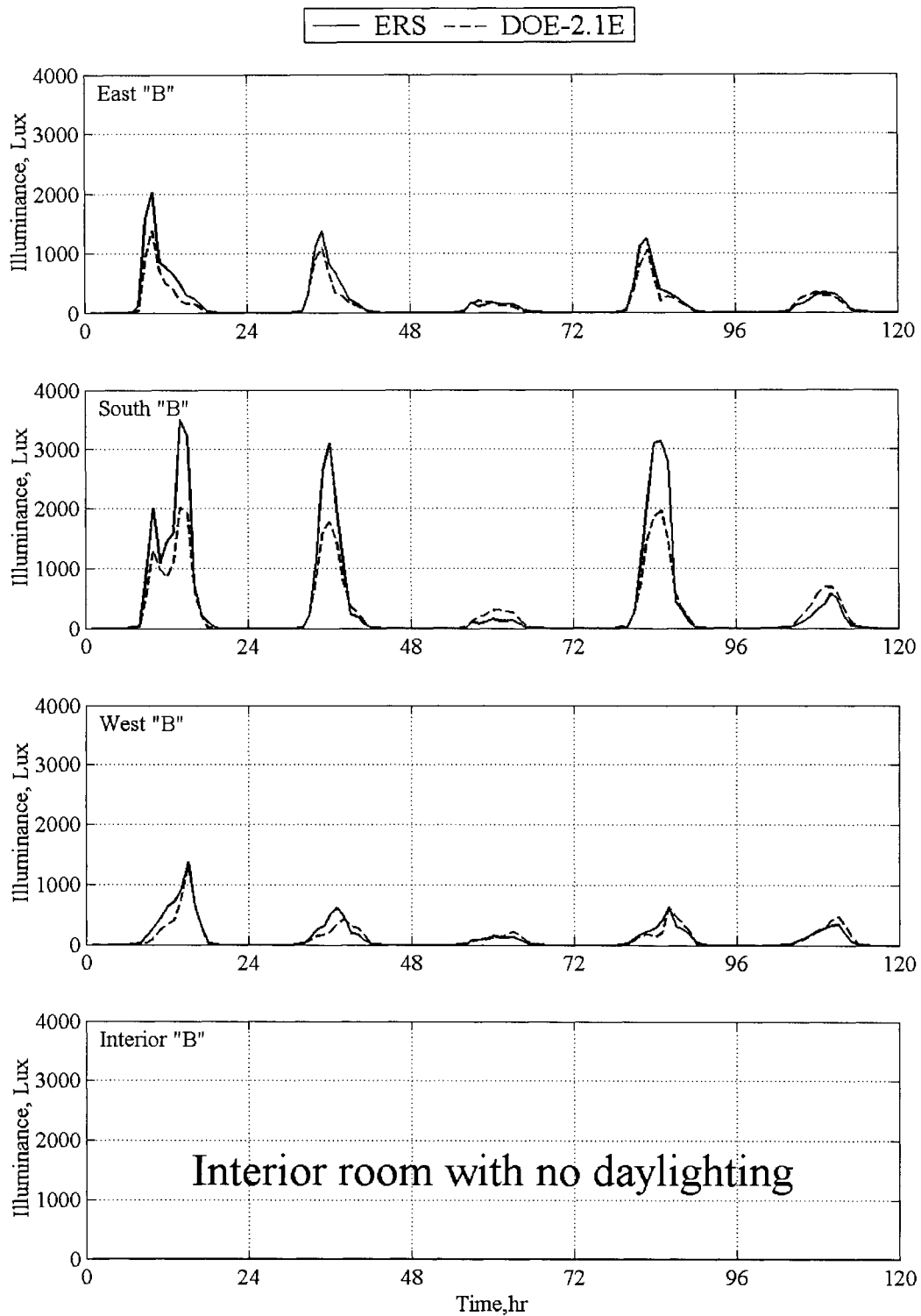


Figure 5.2.3: Illuminance comparisons at the reference point for the "B" rooms Case II.

The “B” test rooms predicted similar results compared with the “A” test rooms. A statistical comparison for the illuminance for the “B” test rooms Case II is shown in Table 5.2.2.

Table 5.2.2: Statistical comparisons for the illuminance for the “B” rooms Case II, in Lux.

Statistics	East “B”		South “B”		West “B”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	170.9	128.6	353.3	263.0	114.6	100.9
σ	4.1	NA	5.9	NA	3.9	NA
s	348.1	253.6	802.8	497.3	213.8	191.3
x_{\max}	2024.0	1381.1	3507.0	2012.7	1377.0	1327.9
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
\bar{D}	NA	42.3	NA	90.3	NA	13.6
D_{\max}	NA	643.4	NA	1494.3	NA	308.2
D_{\min}	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	50.4	NA	137.8	NA	35.3
D_{rms}	NA	117.9	NA	343.8	NA	75.2
SE	NA	32.9	NA	34.3	NA	13.5
IE	NA	39.2	NA	52.4	NA	35.0

There was an apparent bias error for the Li-Cor sensor in the south test room. The results from the east test rooms were comparable. The east and south “B” test rooms seem to predict the results better than in the “A” test rooms. Like in the “A” test rooms, the mean illuminance difference for all the test rooms exceeded the 95% uncertainty bounds.

Zone Light Power

Zone light power was measured during the experiment and compared with predicted results from DOE-2.1E. The “A” test rooms were configured to run at maximum capacity when the lights were scheduled on. The light power results for the “A” test rooms for Case II are shown in Figure 5.2.4.

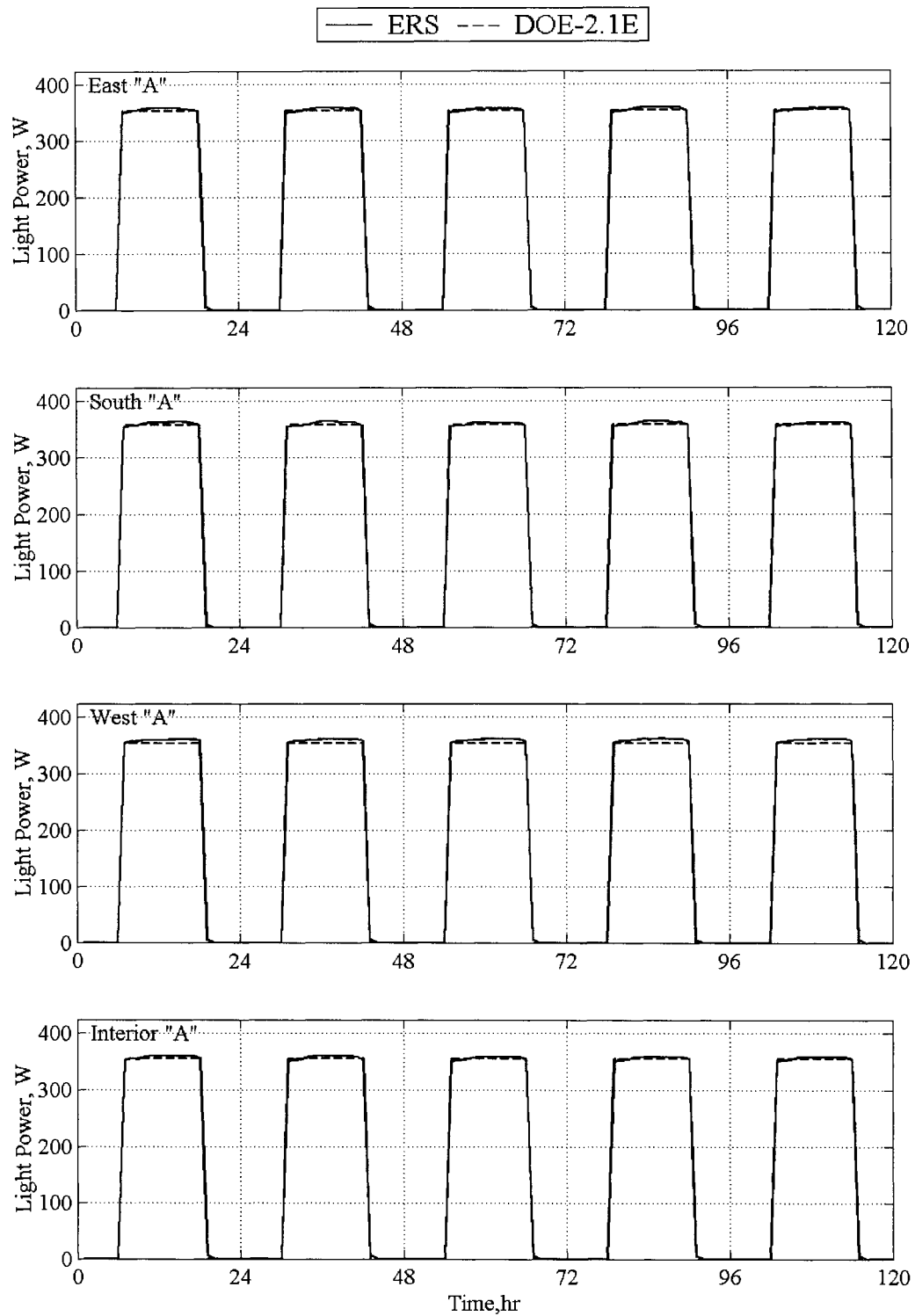


Figure 5.2.4: Light power comparisons for the "A" rooms Case II.

The light power and schedule was a user input rather than a DOE-2.1E validation parameter. Therefore the plots in Figure 5.2.4 verify that the light power and schedule were

entered to the simulation correctly; therefore, statistical comparisons were not performed. Dimmable ballasts were enabled on the “B” exterior test rooms. Both the DOE-2.1E simulation and the experiment varied the light power, which was a function of the illuminance, to maintain a fixed light level at the reference point. These results are shown in Figure 5.2.4.

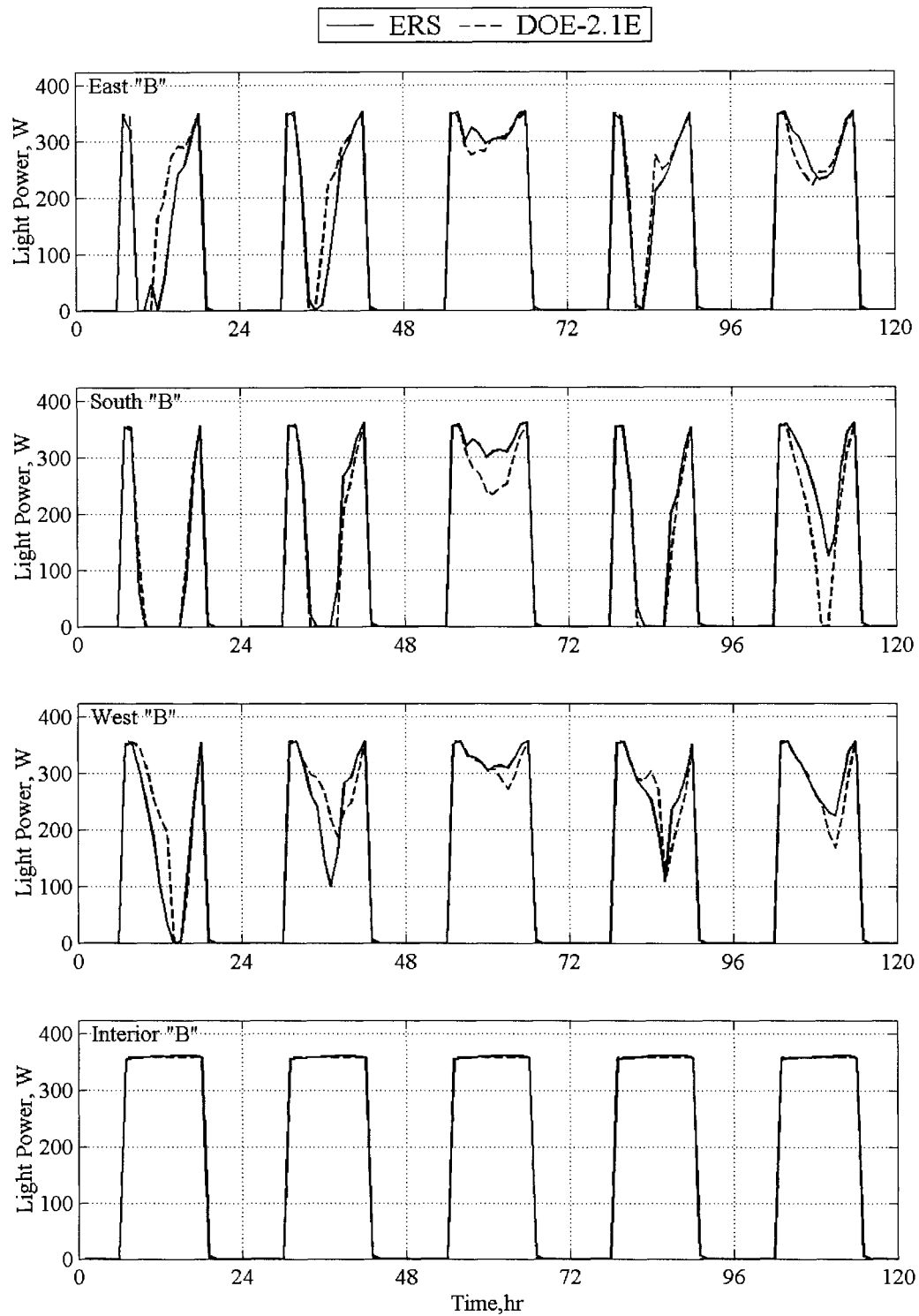


Figure 5.2.5: Light power comparisons for the "B" rooms Case II.

The lights were seldom shut off in the west test room. Whereas, the south and east test rooms were exposed to higher magnitudes of illuminance. This trend corresponds to the

results seen from the zone illuminance. Table 5.2.3 contains the light power comparisons for the “B” test rooms Case II.

Table 5.2.3: Statistical comparisons for light power in the “B” rooms Case II, in W.

Statistics	East “B”		South “B”		West “B”	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	121.7	127.7	110.5	98.5	136.3	139.5
σ	0.1	NA	0.1	NA	0.1	NA
s	148.5	149.4	150.4	142.1	151.3	151.7
x_{\max}	354.0	350.3	361.0	356.8	358.0	356.8
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0
D	NA	-6.0	NA	11.9	NA	-3.2
D_{\max}	NA	164.1	NA	193.0	NA	163.6
D_{\min}	NA	0.0	NA	0.0	NA	0.0
D	NA	12.9	NA	13.9	NA	14.2
D_{rms}	NA	31.9	NA	32.4	NA	32.1
SE	NA	-4.7	NA	12.1	NA	-2.3
IE	NA	10.1	NA	14.1	NA	10.2

Relatively small instantaneous and simulation errors were seen in the east and west test rooms. This is in sharp contrast to the results seen in Case I. This was probably due to the path of the sun and a relatively cloudy set of test days.

For the south test room, the instantaneous error (hour-by-hour calculation) and the summary error were about 15%, which indicated that the simulation consistently under-predicted the light power to the space on an hour-by-hour basis. The average light power differences exceeded the 95% uncertainty bounds for all test rooms.

Zone Airflow Rate

The airflow rates for the “A” test rooms are shown in Figure 5.2.6. Cooling was generally required during the day because lights and baseboard heaters transferred heat to the space.

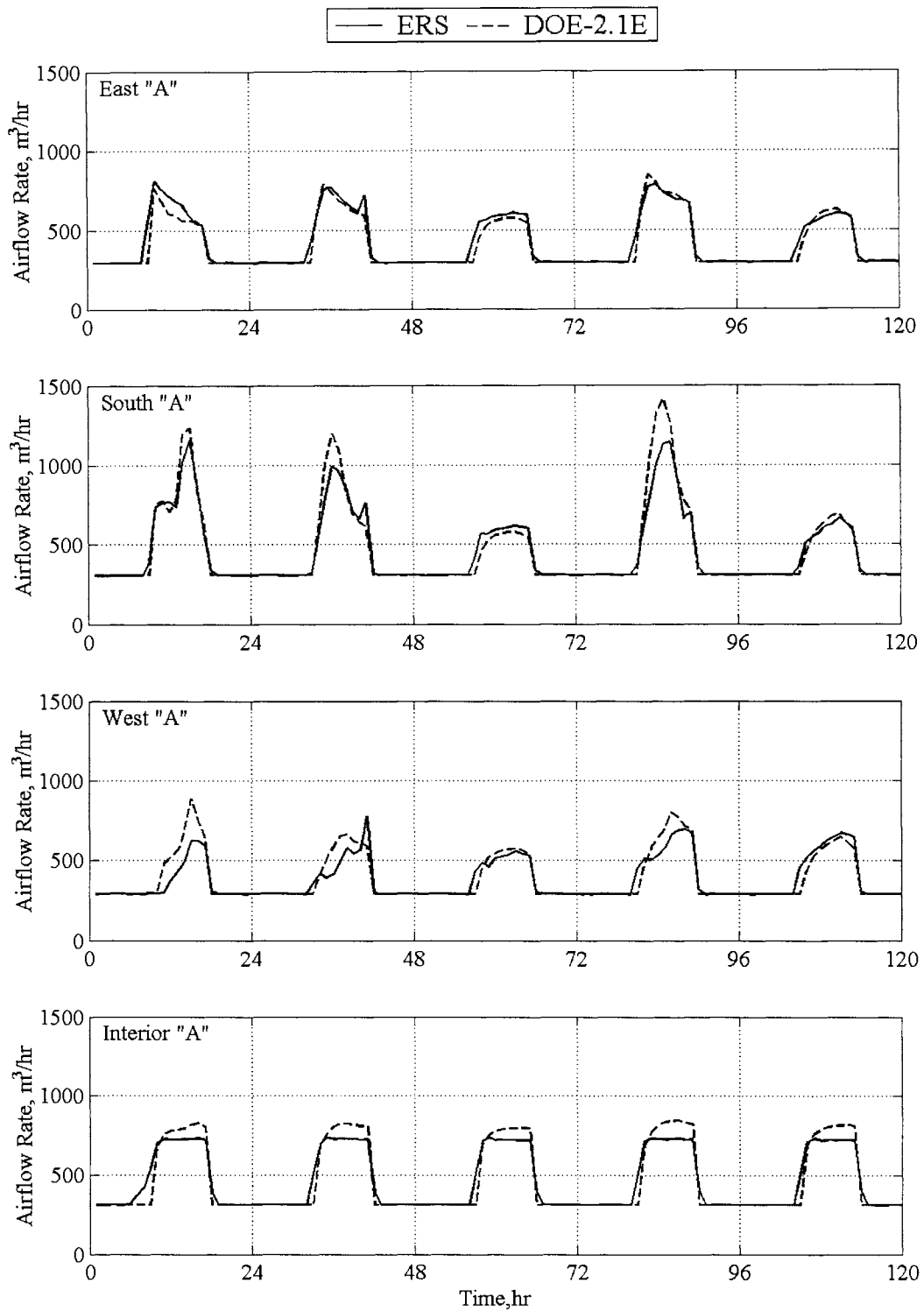


Figure 5.2.6: Zone airflow rates for the "A" rooms.

The predicted airflow rates seemed to follow the general trend seen in the experiment. There were some discrepancies in the interior test room. These discrepancies seem to indicate that the DOE-2.1E simulation was over-predicting the cooling load. The load in the test room was not a function of outdoor conditions; the only load in the space was a result of the baseboard heat and light load. Seemingly there was some experimental error, possibly in the thermostat calibration. The thermostat also could have read the temperature accurately, but variances in the room temperature could have caused errors. Comparative statistics for the airflow rates in the “A” test rooms are shown in Table 5.2.4.

Table 5.2.4: Statistical comparison for the airflow rates for the “A” rooms Case II, in m³/hr.

Statistics	East “A”		South “A”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	421.1	407.4	452.7	462.0	380.9	391.7	462.2	469.6
σ	20.2	NA	41.7	NA	32.2	NA	51.4	NA
s	168.8	163.7	226.0	266.3	134.3	156.5	191.6	228.0
x_{\max}	806.0	847.0	1157.0	1412.0	780.0	890.0	738.0	845.0
x_{\min}	294.0	298.0	304.0	306.0	290.0	291.0	310.0	310.0
\bar{D}	NA	13.7	NA	-9.3	NA	-10.9	NA	-7.4
D_{\max}	NA	260.0	NA	322.0	NA	266.0	NA	238.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	20.5	NA	30.6	NA	31.4	NA	37.3
D_{rms}	NA	43.9	NA	66.5	NA	63.7	NA	65.1
SE	NA	3.4	NA	-2.0	NA	-2.8	NA	-1.6
IE	NA	5.0	NA	6.6	NA	8.0	NA	7.9

Overall the instantaneous and simulation errors were relatively small. From the simulation error values, the DOE-2.1E over-predicted the airflow rate in the east test room while under-predicted the other test room airflow rates. The average airflow rate differences for the zones were within the 95% uncertainty bounds. The airflow rates for the “B” test rooms are shown in Figure 5.2.7.

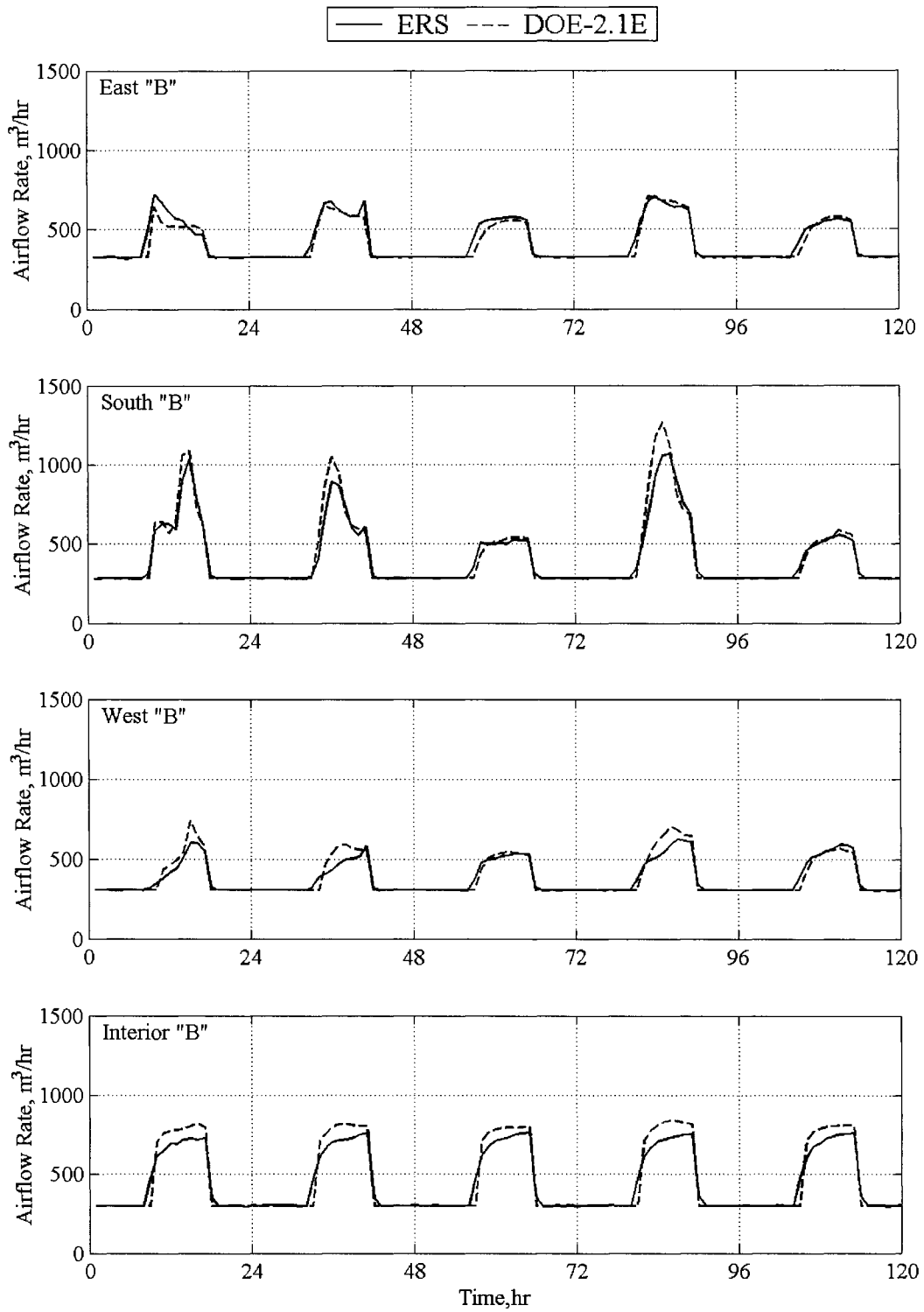


Figure 5.2.7: Zone airflow rates for the "B" rooms Case II.

From Figure 5.2.7, the predicted airflow rates from the DOE-2.1E simulation compared well with experiment. The statistical comparisons for the airflow rates from the “B” test rooms are shown in Table 5.2.5.

Table 5.2.5: Statistical comparison for the airflow rates for the “B” rooms Case II, in m³/hr.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	415.9	405.2	407.9	416.4	380.1	386.3	444.9	462.2
σ	41.9	NA	42.5	NA	32.4	NA	89.1	NA
s	128.5	123.1	199.3	228.7	105.9	123.9	193.3	234.0
x_{\max}	719.0	706.0	1065.0	1267.0	631.0	745.0	764.0	840.0
x_{\min}	318.0	323.0	281.0	283.0	306.0	307.0	293.0	298.0
\bar{D}	NA	10.7	NA	-8.4	NA	-6.2	NA	-17.2
D_{\max}	NA	166.0	NA	239.0	NA	140.0	NA	175.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	16.5	NA	23.1	NA	18.4	NA	36.8
D_{rms}	NA	34.2	NA	50.8	NA	35.8	NA	60.7
SE	NA	2.6	NA	-2.0	NA	-1.6	NA	-3.7
IE	NA	4.1	NA	5.5	NA	4.8	NA	8.0

The summary error for the test rooms was relatively small. Like in the “A” test rooms, the same trends for predictions were found. As seen for the “A” zones, all the average difference for the zones airflow rates were within the 95% uncertainty bounds.

Zone Reheat Power

Zone heat for Case II was provided to the test rooms from hydronic coils in the zone VAV box. The same energy balance for Case I was used to calculate the reheat power for Case II. The plots for the A” test rooms are shown in Figure 5.2.8.

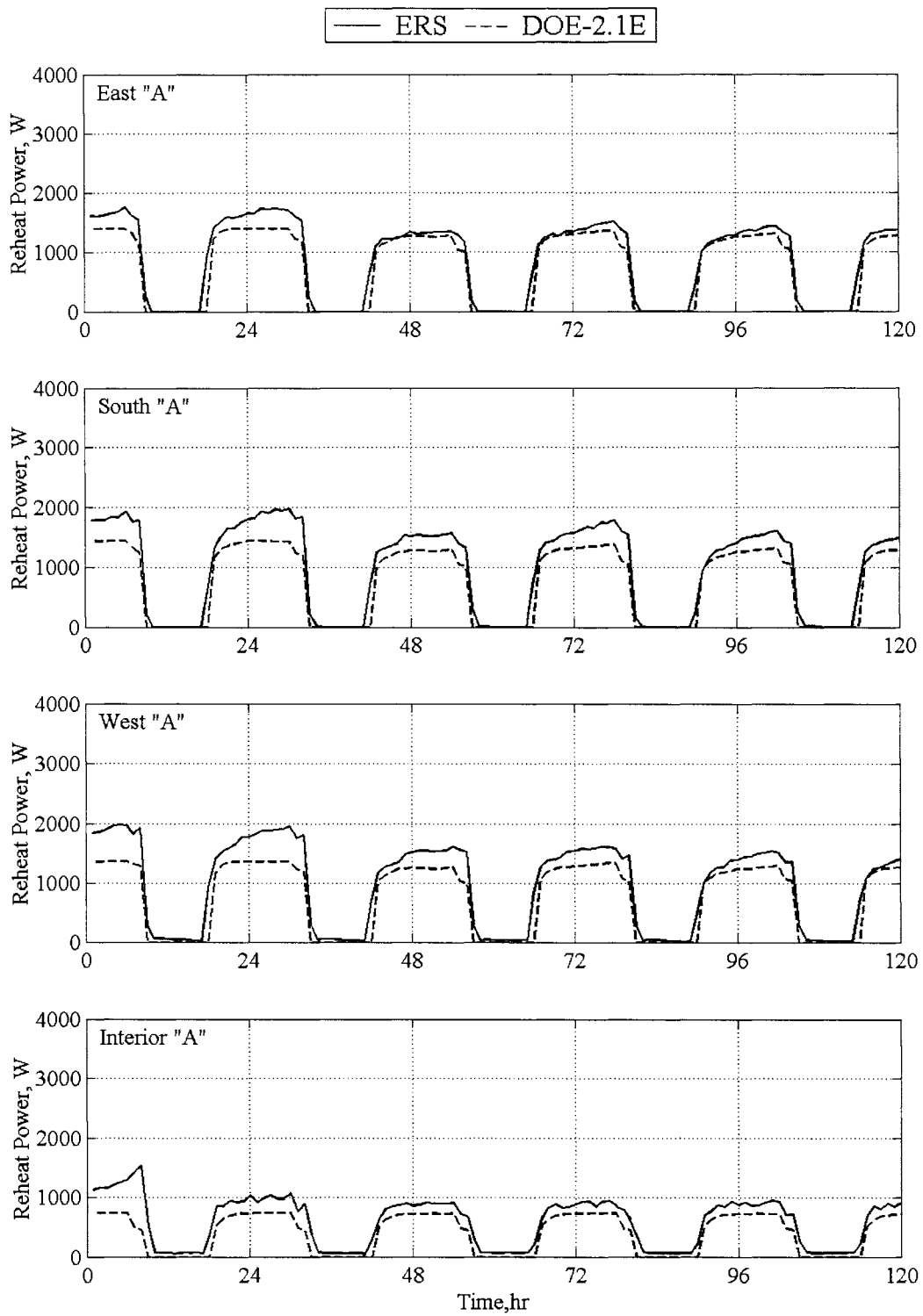


Figure 5.2.8: Reheat power for the "A" rooms Case II.

Compared with the reheat plots from Case I, the discrepancies seen in the plot are much smaller. These comparisons can be more accurately quantified by the statistical comparisons shown in Table 5.2.6.

Table 5.2.6: Statistical comparison for the reheat power for the “A” rooms Case II, in W.

Statistics	East “A”		South “A”		West “A”		Interior “A”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	857.5	734.7	950.4	742.7	959.8	727.7	576.8	386.4
σ	256.1	NA	435.6	NA	355.7	NA	339.1	NA
s	682.2	629.7	762.8	637.3	738.2	623.0	418.0	336.7
x_{\max}	1752.0	1402.0	1975.0	1440.0	1986.0	1370.0	1534.0	736.0
x_{\min}	0.0	0.0	0.0	0.0	10.0	0.0	48.0	0.0
\bar{D}	NA	122.8	NA	207.8	NA	232.1	NA	190.4
D_{\max}	NA	884.0	NA	711.0	NA	927.0	NA	1078.0
D_{\min}	NA	0.0	NA	0.0	NA	10.0	NA	48.0
$ D $	NA	123.4	NA	208.2	NA	232.1	NA	190.4
D_{rms}	NA	199.6	NA	282.0	NA	312.7	NA	246.1
SE	NA	16.7	NA	28.0	NA	31.9	NA	49.3
IE	NA	16.8	NA	28.0	NA	31.9	NA	49.3

The DOE-2.1E simulation tended to under-predict the reheat power. This is shown by the similar error values that were calculated from the instantaneous and simulations errors. Despite the discrepancies, the results were far better than those seen in Case I. Prior to the test, a series of stratification test were performed. These results indicated large amounts of stratification in the test rooms. Fans were mounted on the ceiling to force warmer air to mix with the cooling air, rather than enter the return plenum. Another correction made dealt with the zone airflow rates. Immediately after the test, independent airflow measurements were taken in the room to identify and correct airflow measurements from the building controls. Correlations were developed and the airflow rates for Case II were post-processed. All of the average reheat power differences were within the 95% uncertainty bounds.

The results for the reheat power for the “B” test rooms are shown in Figure 5.2.9.

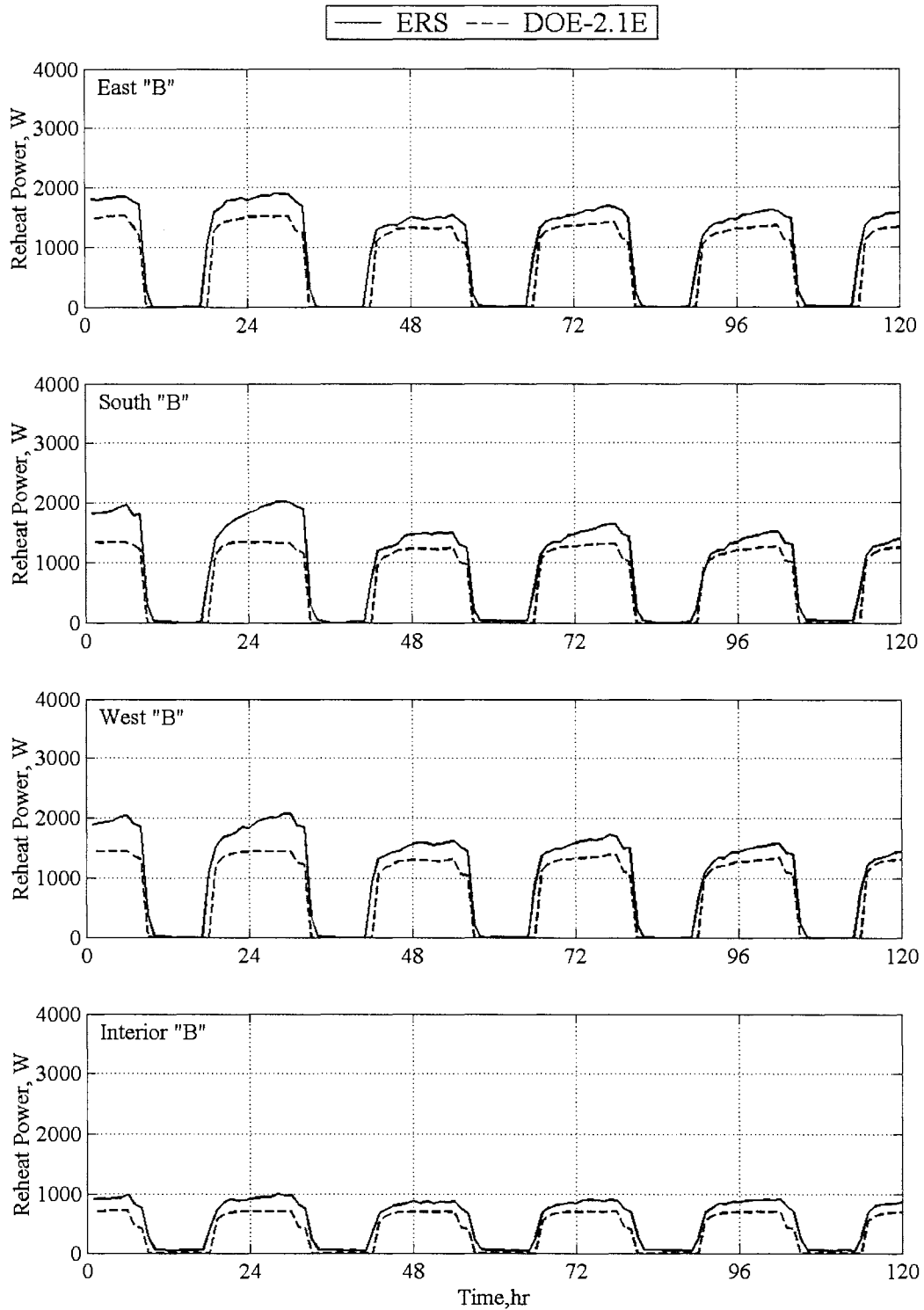


Figure 5.2.9: Reheat power for the "B" rooms Case II.

The statistical comparisons for the "B" test rooms can be found in Table 5.2.7.

Table 5.2.7: Statistical comparison for the reheat power for the “B” rooms Case II, in W.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	973.6	773.3	927.4	708.7	987.1	752.7	532.8	374.8
σ	411.5	NA	447.3	NA	345.1	NA	503.6	NA
s	758.5	663.7	737.9	607.1	778.9	645.0	382.3	326.8
x_{\max}	1897.0	1521.0	2021.0	1335.0	2072.0	1446.0	1000.0	709.0
x_{\min}	0.0	0.0	0.0	0.0	0.0	0.0	35.0	0.0
\bar{D}	NA	200.3	NA	218.7	NA	234.3	NA	158.0
D_{\max}	NA	1028.0	NA	744.0	NA	1079.0	NA	402.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	35.0
$ D $	NA	200.3	NA	220.2	NA	234.3	NA	158.0
D_{rms}	NA	279.4	NA	303.6	NA	328.3	NA	184.6
SE	NA	25.9	NA	30.9	NA	31.1	NA	42.2
IE	NA	25.9	NA	31.1	NA	31.1	NA	42.2

Simulation and instantaneous errors comparable to those for the “A” test room were seen for the “B” test rooms. Small discrepancies can be seen in the east and interior test rooms. Like for the “A” test rooms, the DOE-2.1E under-predicted the reheat power required for the space. All the average differences were within the 95% uncertainty bounds.

Zone Temperature

The zone temperatures for both the “A” and the “B” test rooms were measured and predicted by the DOE-2.1E. The graphical results for the zone temperatures in the “A” test rooms are shown in Figure 5.2.10.

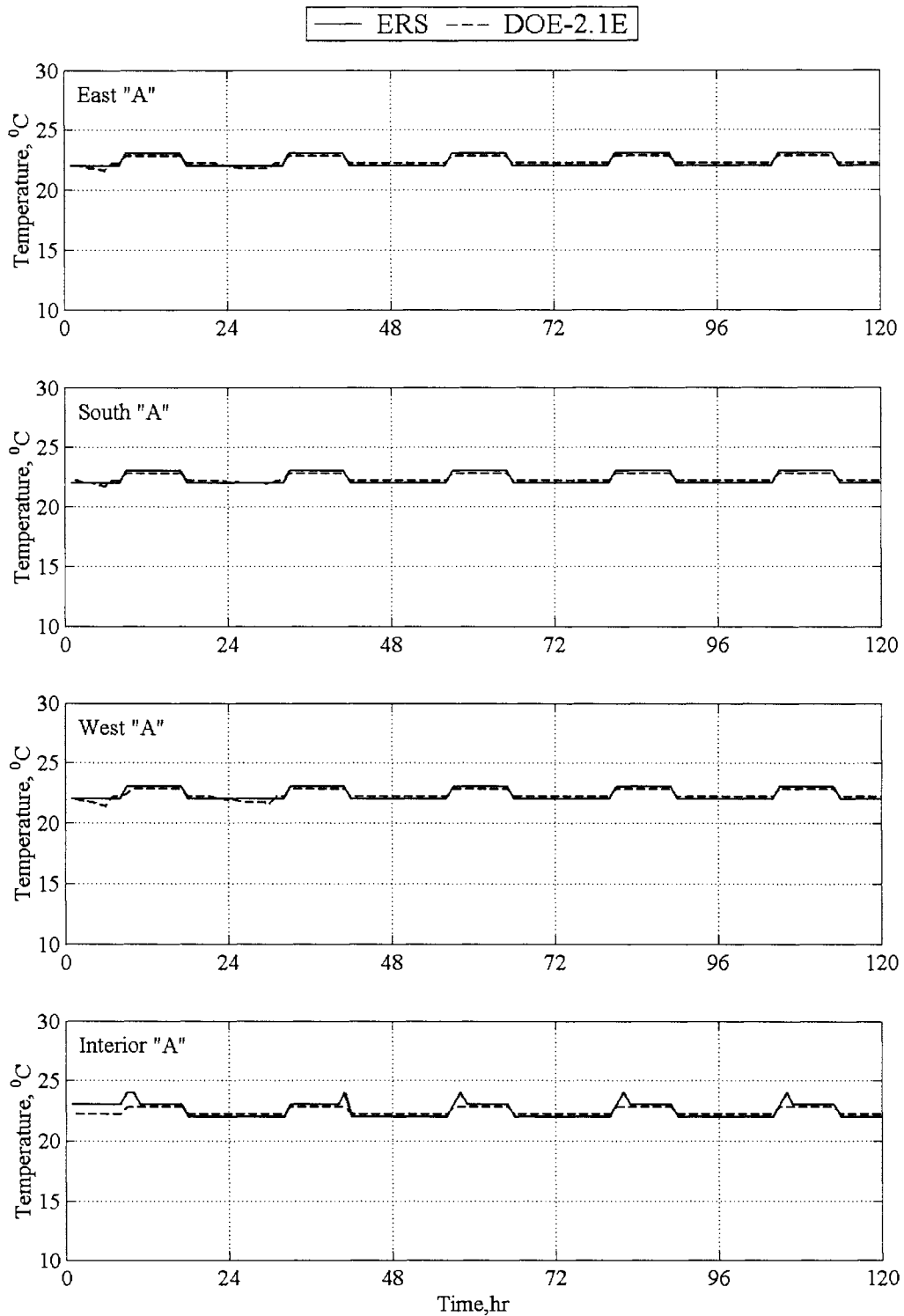


Figure 5.2.10: Zone temperature for the "A" rooms Case II.

During the first day small discrepancies were seen in the interior test room. These discrepancies tended to reappear towards the end of the day throughout the experiment.

Statistical comparisons for the zone temperatures for the “A” test rooms are shown in Table 5.2.8.

Table 5.2.8: Statistical comparisons of zone temperatures for the “A” rooms Case II, in °C.

Statistics	East “A”		South “A”		West “A”		Interior “A”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	22.4	22.4	22.4	22.4	22.4	22.4	22.5	22.4
σ	0.2	NA	0.2	NA	0.2	NA	0.2	NA
s	0.5	0.3	0.5	0.3	0.5	0.4	0.6	0.3
x_{\max}	23.0	22.8	23.0	22.8	23.0	22.8	24.0	22.8
x_{\min}	22.0	21.6	22.0	21.7	22.0	21.4	22.0	22.2
\bar{D}	NA	0.0	NA	0.0	NA	0.0	NA	0.1
D_{\max}	NA	0.4	NA	0.3	NA	0.6	NA	1.2
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.2
$ D $	NA	0.2	NA	0.2	NA	0.2	NA	0.3
D_{rms}	NA	0.2	NA	0.2	NA	0.2	NA	0.4
SE	NA	0.0	NA	-0.1	NA	0.0	NA	0.3
IE	NA	0.9	NA	0.8	NA	0.9	NA	1.3

Overall, the results from the simulation and the experiment were good. Comparisons for the zone temperatures of the “B” test rooms were also made. The zone temperature was a control point for both the simulation and the experiment, where other quantities like airflow rate and reheat were adjusted to maintain the space. Because the system had enough system pressure to maintain the spaces, the rooms were in control and the average differences were within the 95% uncertainty bounds for all the test rooms. The graphical results are shown in Figure 5.2.11.

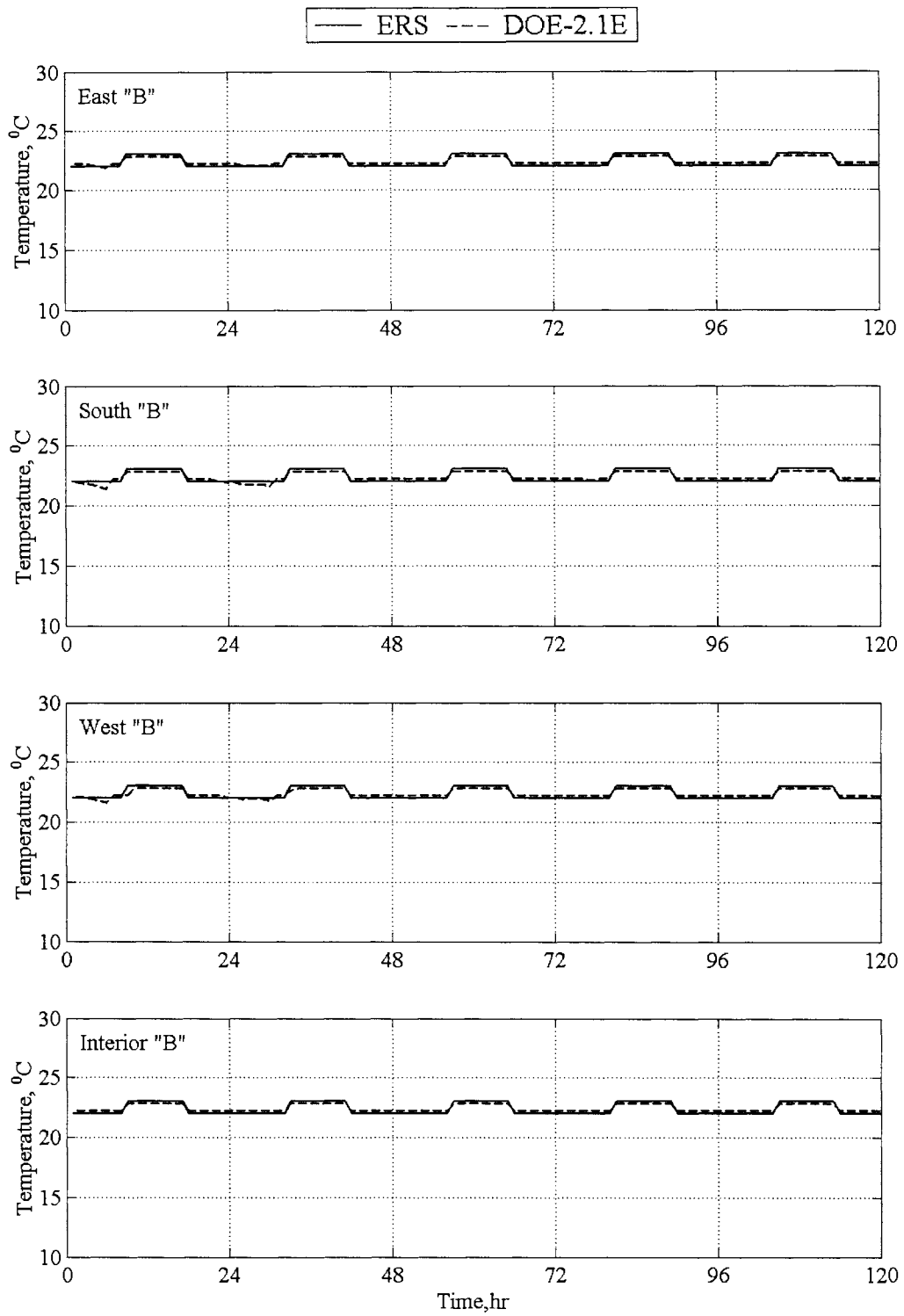


Figure 5.2.11: Zone air temperatures for the "B" rooms Case II.

The statistical comparisons for the zone temperatures in the “B” test rooms are shown in Table 5.2.9.

Table 5.2.9: Statistical comparisons for zone temperatures for the “B” rooms Case II in °C.

Statistics	East “B”		South “B”		West “B”		Interior “B”	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
σ	0.2	NA	0.2	NA	0.2	NA	0.2	NA
s	0.5	0.3	0.5	0.4	0.5	0.3	0.5	0.3
x_{\max}	23.0	22.8	23.0	22.8	23.0	22.8	23.0	22.8
x_{\min}	22.0	21.9	22.0	21.4	22.0	21.6	22.0	22.2
\bar{D}	NA	0.0	NA	0.0	NA	0.0	NA	-0.1
D_{\max}	NA	0.2	NA	0.6	NA	0.8	NA	0.2
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.2
$ D $	NA	0.2	NA	0.2	NA	0.2	NA	0.2
D_{rms}	NA	0.2	NA	0.2	NA	0.2	NA	0.2
SE	NA	-0.2	NA	0.0	NA	-0.1	NA	-0.2
IE	NA	0.9	NA	0.9	NA	0.9	NA	0.9

The simulation and instantaneous errors for all the test rooms were approximately the same and negligible.

System Comparisons

System parameters from the experiment were compared with the DOE-2.1E simulation predictions. The following system parameters were compared:

- Supply airflow rates.
- Return air temperatures.
- Leaving coil air temperatures.
- Cooling heat transfer rates.

A brief description of each quantity and graphical and statistical parameters are provided in this section.

Supply Airflow Rate

The supply airflow rate was the sum of the room airflow rates for the respective systems. The values closely corresponded to the return airflow rate because the systems were configured to use 100% re-circulated air.

Return Air Temperature

The return air temperature was the temperature measured in the return air duct. This generally corresponded well with the room air temperatures.

Leaving Coil Temperature

The leaving coil temperature was measured by a thermocouple array and the value reported by the data acquisition system was the arithmetic average. This was done to account for changes in the temperature due to the turbulent thermal boundary layer as well as buoyancy effects within a larger duct. The temperature was taken prior to the supply fan and was lower than the controlled supply air temperature.

Cooling Heat Transfer Rate

The cooling heat transfer rate was a calculation of the amount of energy removed from the air stream by the cooling coils. No direct measurement for the cooling heat transfer rate was possible, therefore as in Case I, and energy balance was used to quantify the cooling heat transfer rate.

System Results

The graphical results for the “A” system are shown in Figure 5.2.12 for the experiment and the DOE-2.1E simulation.

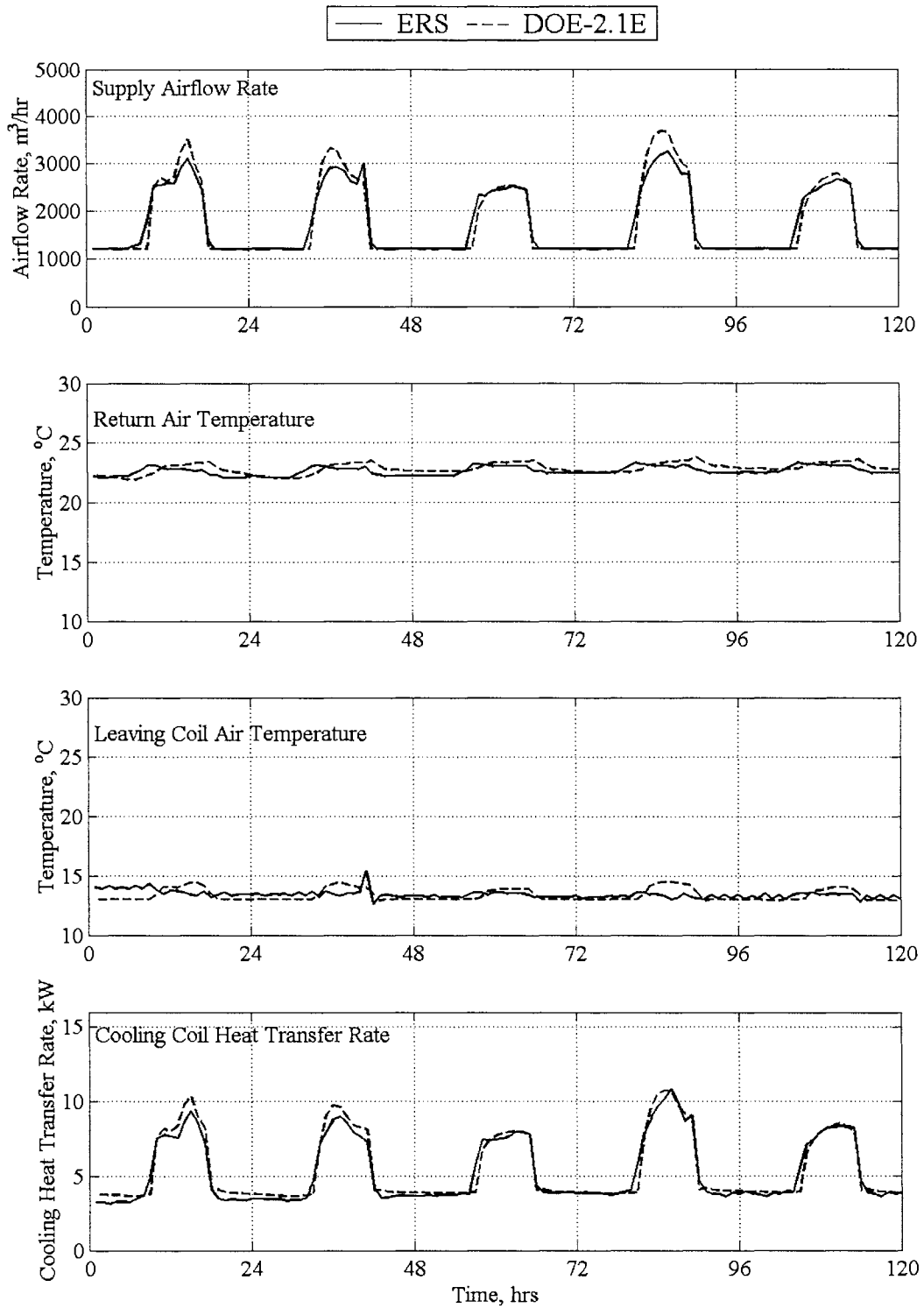


Figure 5.2.12: System "A" parameters for Case II.

As seen from the plots, the simulation did a fair job of predicting the system parameters. Perhaps more indicative were the statistical comparisons for the “A” system shown in Table 5.2.10.

Table 5.2.10: Statistical comparison for the “A” system Case II.

Statistics	Supply Airflow Rate, m ³ /hr		Return Air Temp, °C		Leaving Coil Temp, °C		Cooling HTR, KW	
	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E	ERS	DOE2.1E
\bar{x}	1716.9	1730.0	22.6	22.8	13.4	13.3	5.3	5.4
σ	76.3	NA	0.2	NA	0.2	NA	1.2	NA
s	687.0	784.1	0.4	0.4	0.3	0.5	2.2	2.3
x_{\max}	3246.0	3679.0	23.3	23.8	15.4	14.5	10.8	10.7
x_{\min}	1201.0	1204.0	22.1	21.9	12.6	12.9	3.1	3.6
\bar{D}	NA	-13.1	NA	-0.2	NA	0.1	NA	-0.1
D_{\max}	NA	592.0	NA	1.1	NA	1.5	NA	2.0
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	92.1	NA	0.4	NA	0.5	NA	0.3
D_{rms}	NA	180.8	NA	0.4	NA	0.6	NA	0.5
SE	NA	-0.8	NA	-1.0	NA	0.5	NA	-2.7
IE	NA	5.3	NA	1.7	NA	3.5	NA	6.4

The simulations and instantaneous errors were very small for the “A” system. Graphical comparisons for “B” system were made with the same parameters. The average differences for the supply airflow rate, cooling heat transfer rate, and leaving coil temperature fall within their 95% uncertainty bounds, whereas the return air temperature does not fall within its 95% uncertainty bounds. The graphical comparisons are shown in Figure 5.2.13.

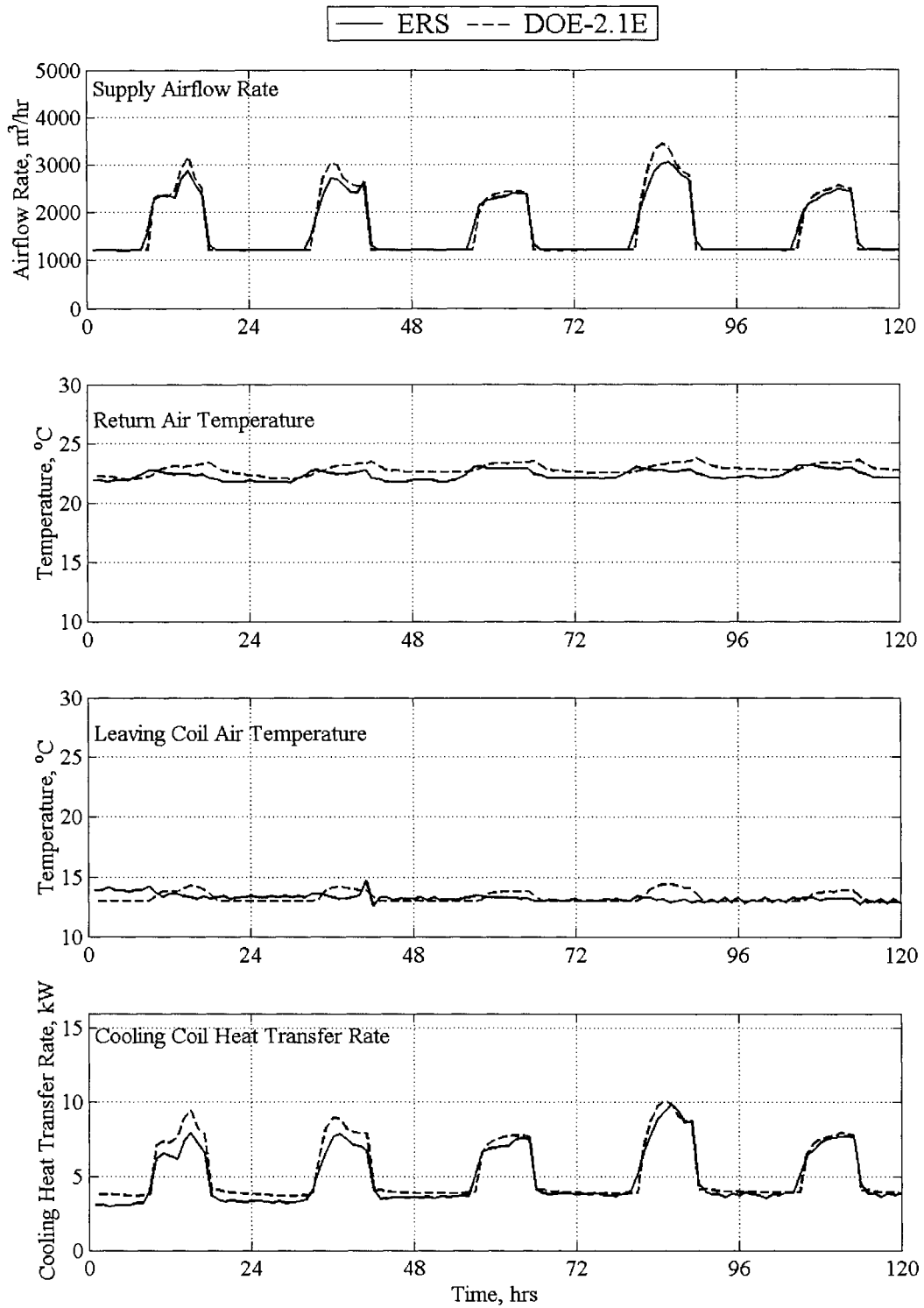


Figure 5.2.13: System “B” parameters for Case II.

The statistical comparisons for the “B” system are shown in Table 5.2.11.

Table 5.2.11: Statistical comparison for the “B” system Case II.

Statistics	Supply Airflow Rate, m ³ /hr		Return Air Temp, °C		Leaving Coil Temp, °C		Cooling HTR, kW	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	1648.8	1669.9	22.3	22.8	13.3	13.3	4.9	5.3
σ	112.0	NA	0.2	NA	0.2	NA	1.6	NA
s	600.9	682.7	0.4	0.4	0.3	0.5	1.9	2.0
x_{\max}	3044.0	3435.0	23.1	23.7	14.7	14.4	9.8	10.1
x_{\min}	1206.0	1211.0	21.7	22.0	12.6	12.9	3.0	3.7
\bar{D}	NA	-21.1	NA	-0.5	NA	0.0	NA	-0.4
D_{\max}	NA	437.0	NA	1.4	NA	1.5	NA	1.5
D_{\min}	NA	0.0	NA	0.0	NA	0.0	NA	0.0
$ D $	NA	68.3	NA	0.6	NA	0.4	NA	0.4
D_{rms}	NA	131.7	NA	0.6	NA	0.5	NA	0.6
SE	NA	-1.3	NA	-2.2	NA	-0.3	NA	-6.7
IE	NA	4.1	NA	2.5	NA	3.2	NA	8.5

The predicted values for the system “B” DOE-2.1E simulation were comparable to the predicted values for the system “A” predictions. The average differences for the supply airflow rate and the cooling heat transfer rate fall within their 95% uncertainty bounds, whereas the return air temperature and the leaving coil temperature do not fall within their 95% uncertainty bounds. Larger uncertainty bounds were seen for the “B” supply airflow rates and cooling heat transfer rates because there were larger uncertainty bands for the regression analysis for the “B” test rooms.

5.3 Room Stratification

For the daylight tests, the reheat was engaged when the airflow rate was at the minimum position. Due to the relatively low minimum airflow rates, little kinetic energy (throw) was available when the air exited the supply diffuser and entered the room. Therefore, buoyancy effects (the entering air had a significantly higher temperature than the space air) caused the heated air to remain at the ceiling and exit through the return diffuser. Because of this phenomenon, the energy needed to heat the room was either in the plenum or the return air system. Because the air did not migrate down to the thermostat height, the zone controls perceived that more energy was required to heat the space resulting in inflated experimental reheat results.

A test was done in January 2003 (between Case I and Case II) to identify the extent of the room stratification problem. For the experiment, resistant temperature devices (RTD) were mounted on two stands in the East “B” test room at varying heights. One of the stands was placed near the exterior wall and the other was mounted near the interior wall. Large temperatures gradients from floor to ceiling were measured in the test room. To eliminate the stratification problem, force convection (ceiling fans) was used to force the hotter air from the ceiling into the space. By adding additional kinetic energy in the direction of the floor, the buoyancy forces associated with the air entering the space were overcome; thus a more uniform temperature was seen throughout the test rooms. Figures 3.3.1a and 3.3.1b show the temperature distributions for the RTD stands taken during the experiment before and after the installation of a ceiling fan.

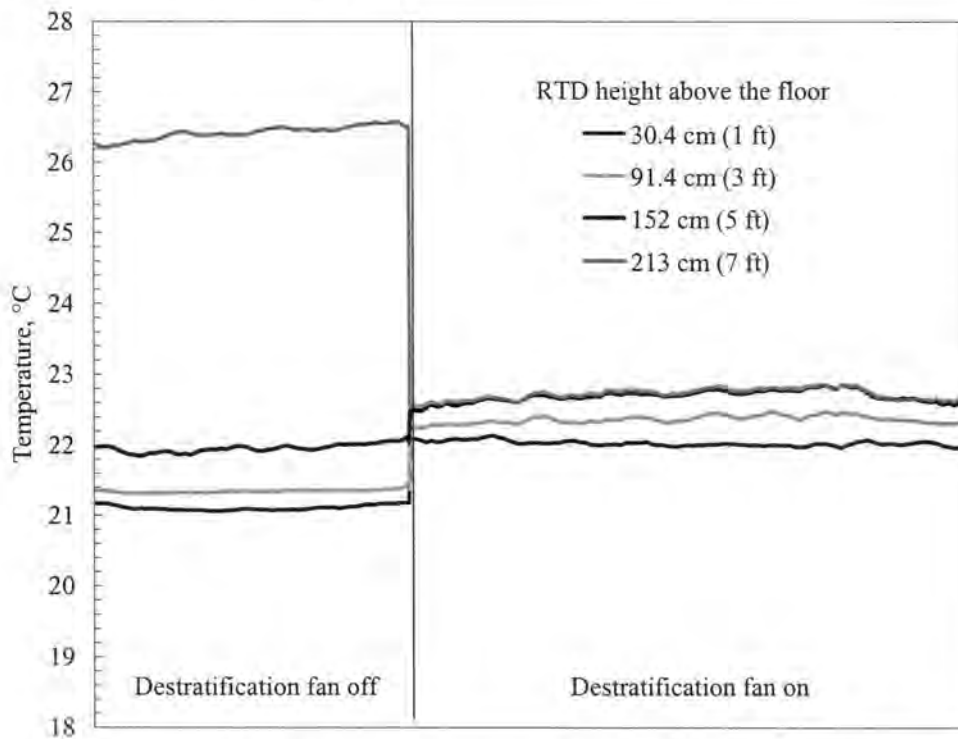


Figure 3.3.1a: Temperature sensors located near windows.

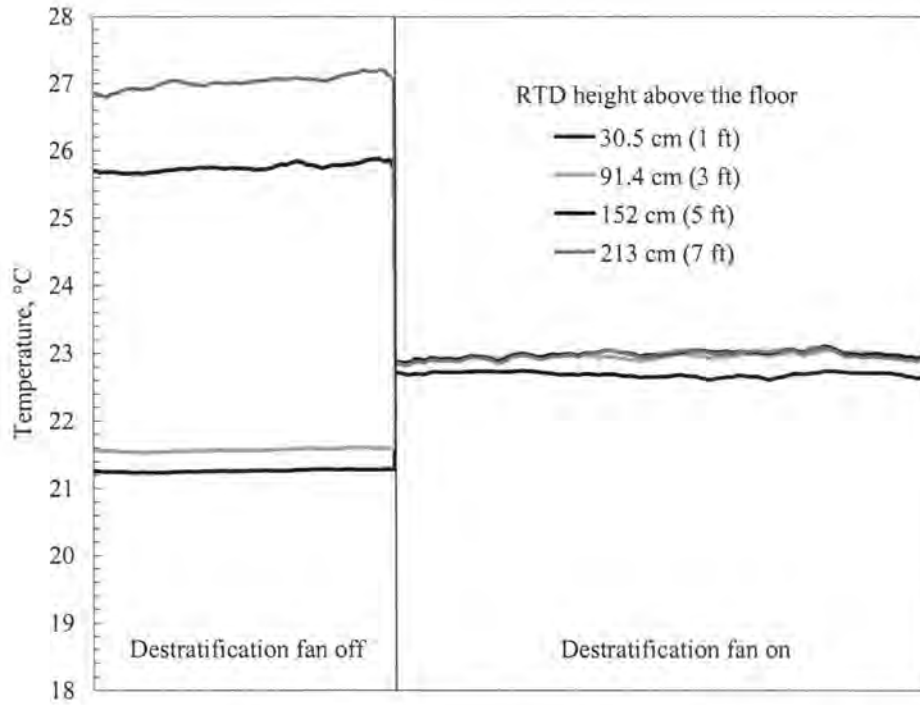


Figure 3.3.1b: Temperature sensors located near the back wall.

A larger velocity effect the inside film coefficient. During the tests the air velocities near the exterior wall before and after the installation of ceiling fans. The velocity at exterior wall increased by a factor of 12 when the ceiling fans were installed. Therefore, a turbulent similarity solution was used to calculate the impact on the inside film coefficient. The proposed inside film coefficient was calculated using a turbulent flat model and is shown in Equation 3.3.1 assuming the velocity was the only property to change in the relationship.

$$h_p = h_i \left(\frac{\bar{V}_p}{\bar{V}_c} \right)^{\frac{4}{5}} \quad (3.3.1)$$

where

h_i is the inside film coefficient before the fans were installed.

\bar{V}_p is the velocity that was measured after the ceiling fans were installed.

\bar{V}_c is the velocity measured before the ceiling fans were installed.

Chapter 6: Economizer Test Results

The results from an Economizer Test run from May 2 to May 5, 2002 are described in this section. The “A” and the “B” test rooms were set up identically so that both systems would see the same load. The economizer control was enabled for the “A” system, while the “B” system operated a 20% damper position. Economizer control for the “A” system operated when the outdoor dry-bulb temperature was less than the temperature of the return air. If the return temperature was greater than the outdoor dry-bulb temperature, the outside air damper closed to a 20% damper position.

The results for the economizer test are divided into three sections: weather comparison, system comparison, and fixed damper comparisons.

6.1 Weather Comparisons

As in the daylight tests, the weather played a primary role in driving the room loads. For the economizer tests, the weather impacted the system performance and parameters. During the experiment, both systems mixed outside air with the return air to maintain ventilation requirements. When in economizer mode, the “A” system also used outside air to remove or subsidize the system cooling when the system return air temperature exceeded the outside dry-bulb temperature. Figure 6.1.1 contains the weather information from the DOE-2.1E building simulation and the experiment.

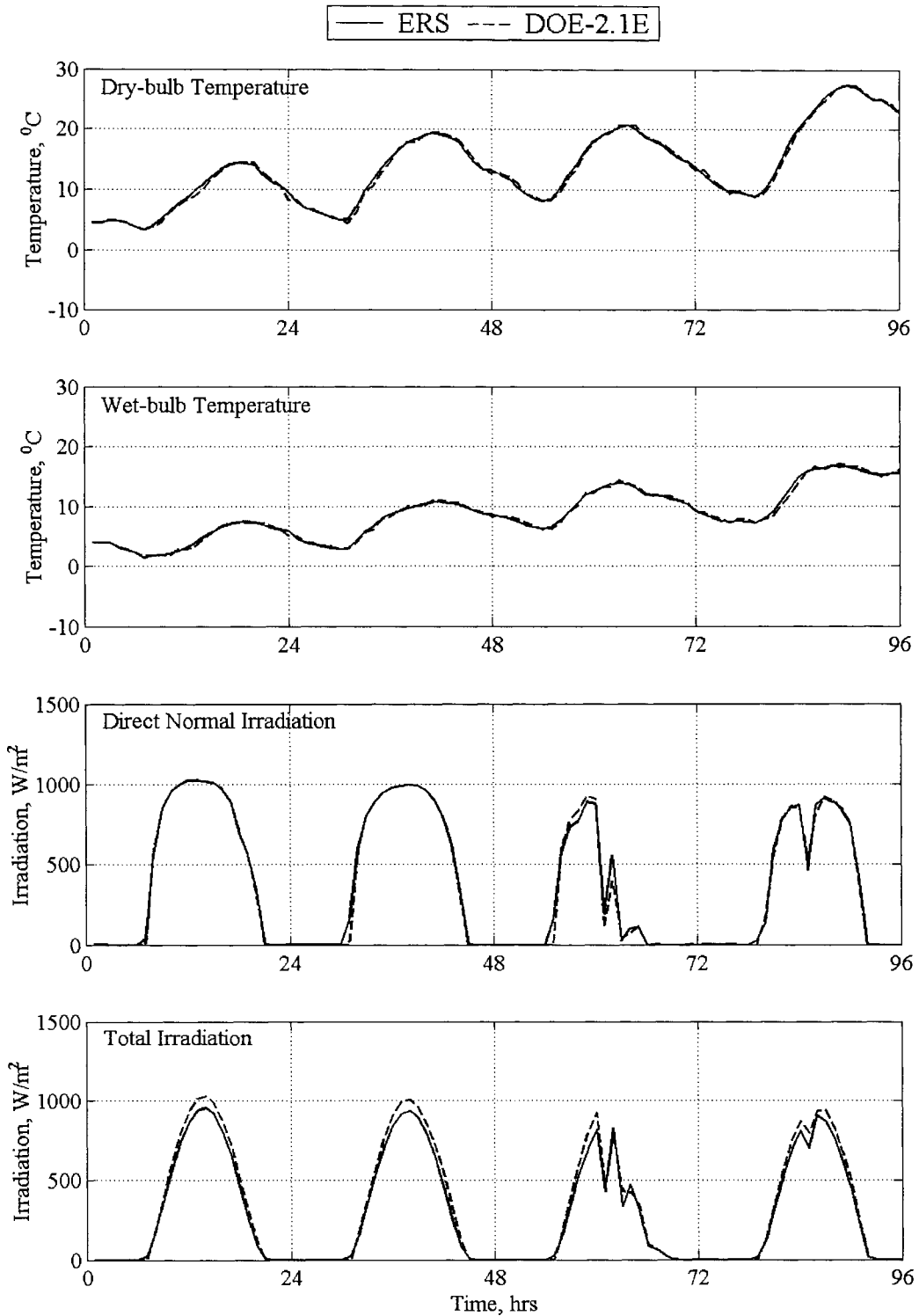


Figure 6.1.1: Weather conditions for the economizer test.

From Figure 6.1.1, general observation pertaining to system performance and room loads can be estimated. Assuming that the return air temperature was similar to the zone

temperatures, predictions about when the economizer control for the “A” system could be made using the outside dry-bulb temperature. If the return air temperature was estimated as 23°C, the economizer for the “A” system would be enabled for the first three days. On the fourth day, the economizer would be enabled in the morning, but when the outdoor air temperature exceeded the return air temperature, the “A” system would return to its prescribed minimum position.

6.2 System Comparisons

The control scheme primarily focused on the system performance, which was ultimately driven by the room loads. Comparisons between the system performance of the experiment and the DOE-2.1E building simulation were made for the systems temperatures and system airflow rates and cooling heat transfer rate.

System Temperatures

The temperatures for the system were measured and compared with the DOE-2.1E building simulation. Figure 6.2.1 contains comparative plots for the return air temperature, mixed air temperature, and leaving coil temperature for the “A” system.

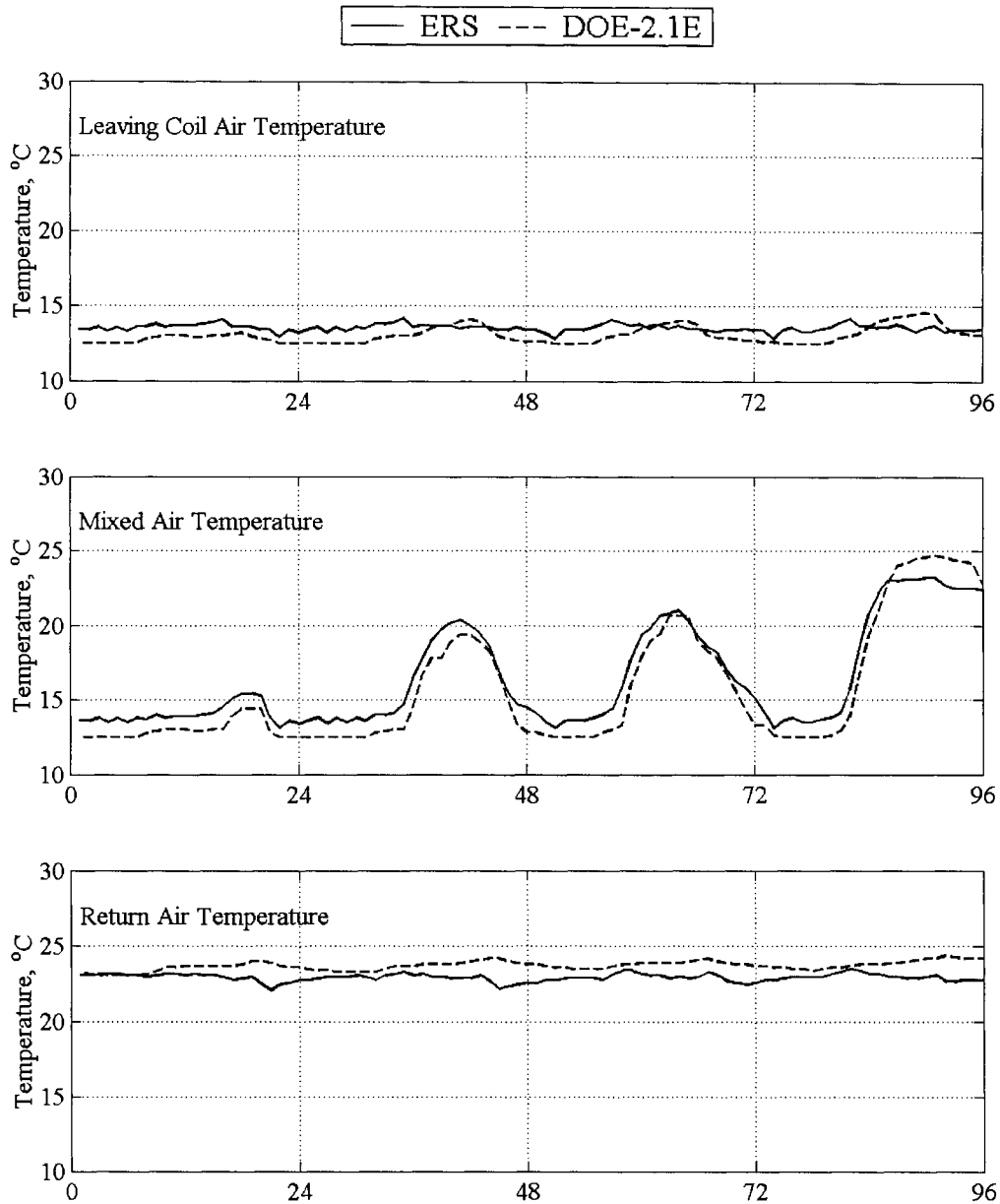


Figure 6.2.2: Temperature measurements for the “A” system.

General comparisons can be made used to estimate the amount of free cooling. The mixed air temperature was the temperature after the return air stream mixes with the outside air stream. When the mixed air temperature was equal to the leaving coil temperature, no additional cooling was required. Statistical comparisons were used to compare the DOE-2.1E building simulation to the experiment. The results of these comparisons are found in Table 6.2.1.

Table 6.2.1: Statistical comparisons for the “A” system temperatures.

Statistics	Leaving Coil Temp, °C		Mixed Air Temp, °C		Return Air Temp, °C	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	13.5	13.0	16.4	15.6	23.0	23.7
σ	0.2	NA	0.2	NA	0.2	NA
s	0.2	0.6	3.3	4.0	0.3	0.3
x_{\max}	14.2	14.6	23.2	24.7	23.5	24.4
x_{\min}	12.8	12.5	13.1	12.5	22.1	23.1
\bar{D}	NA	0.5	NA	0.8	NA	-0.8
D_{\max}	NA	1.2	NA	2.5	NA	2.0
D_{\min}	NA	0.0	NA	0.2	NA	0.0
$ D $	NA	0.7	NA	1.1	NA	0.8
D_{rms}	NA	0.8	NA	1.2	NA	0.9
SE	NA	3.8	NA	5.1	NA	-3.2
IE	NA	5.2	NA	7.1	NA	3.3

Small discrepancies were seen in the system temperatures. The DOE-2.1E building simulation under predicted the leaving coil temperature, but the simulation and instantaneous error were less than 10%. Similar predictions were seen for the mixed air temperature. The building simulation over-predicted the return air temperature. None of the average temperature differences fall within their 95% uncertainty bounds.

Similar temperature comparisons were performed for the “B” system where the economizer control was not enabled. The graphical results are shown in Figure 6.2.3.

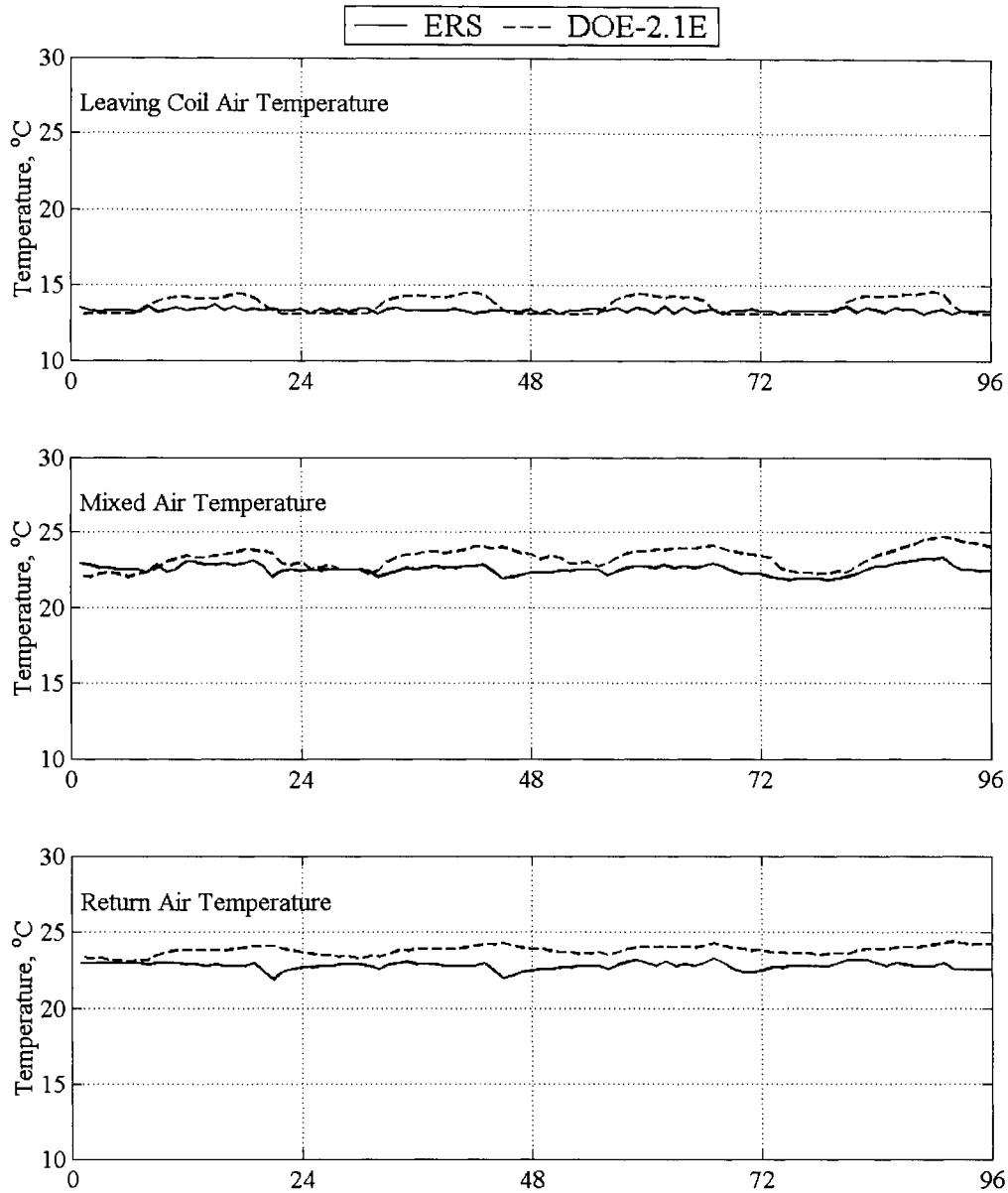


Figure 6.2.3: System “B” temperature comparisons.

The airflow rate for the “B” system remained fixed during the entire test. Therefore, the mixed air temperature did not vary as much as with the “A” system. The plots indicate that the DOE-2.1E over-predicted the all the air temperatures parameters for the “B” system. The statistical comparisons for the “B” system are shown in Table 6.2.2.

Table 6.2.2: Statistical comparisons for the “B” system temperatures.

Statistics	Leaving Coil Temp, °C		Mixed Air Temp, °C		Return Air Temp, °C	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	13.3	13.7	22.5	23.3	22.8	23.8
σ	0.2	NA	0.2	NA	0.2	NA
s	0.1	0.6	0.3	0.7	0.2	0.3
x_{\max}	13.7	14.6	23.3	24.7	23.3	24.4
x_{\min}	13.1	13.0	21.8	22.0	21.9	23.1
\bar{D}	NA	-0.3	NA	-0.8	NA	-1.0
D_{\max}	NA	1.4	NA	2.1	NA	2.3
D_{\min}	NA	0.0	NA	0.0	NA	0.1
$ D $	NA	0.5	NA	0.9	NA	1.0
D_{rms}	NA	0.7	NA	1.0	NA	1.1
SE	NA	-2.5	NA	-3.3	NA	-4.2
IE	NA	3.8	NA	3.7	NA	4.2

From the simulation error parameters and the, the quantitative over-predictions of all the temperature parameters by the DOE-2.1E simulation can be seen. Overall, the both the simulation and instantaneous errors are less than 5%. Like in system “A”, none of the average temperature differences fall within their 95% uncertainty bounds.

System Airflow Rates and Cooling Heat Transfer Rates

For the economizer test, the outside rates brought energy into the system. During the experiment, the minimum airflow rates were controlled by a fixed damper position, which does not mean the outside airflow rate is constant or a fixed percentage of the supply airflow rate. A more detailed explanation is provided in a subsequent section. But for these comparisons, the “A” and “B” systems were assumed to operate identically, and the minimum outside airflow rate was scheduled into the system based on the empirical outside airflow rate for the “B” system.

The cooling heat transfer rate was calculated using the energy balance described for Daylight Case I. The experiment and DOE-2.1E simulations results are graphically compared in Figure 6.2.4 for the “A” system.

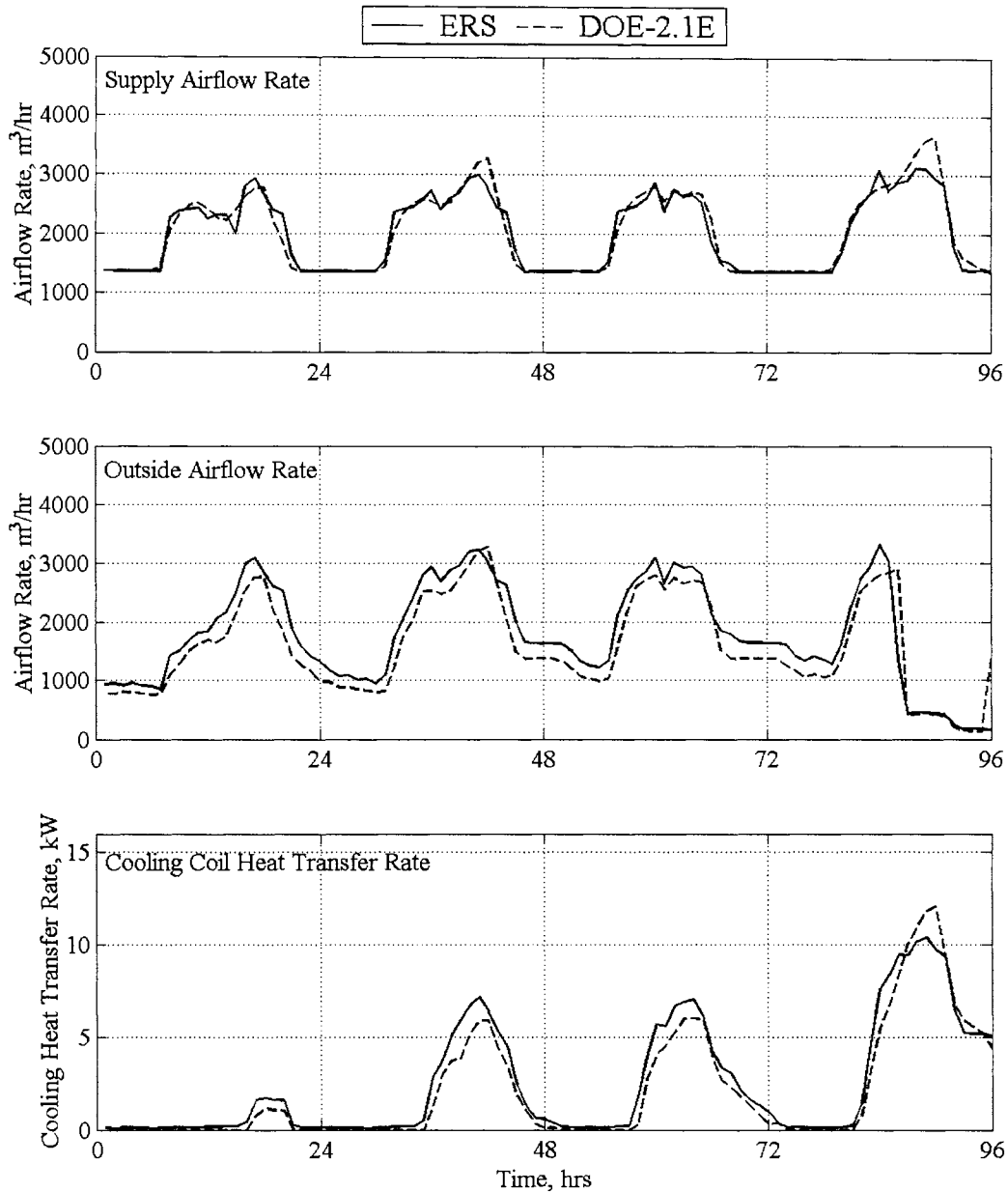


Figure 6.2.4: System “A” airflow rates and cooling coil heat transfer rate comparisons.

From the plots, the predicted supply airflow rates correspond to the actual supply airflow rates. The DOE-2.1E simulation under-predicted the outside airflow rates. For most of the test, the economizer control was enabled and varied to supplement or remove the system cooling. On the last day of the test, the outdoor dry-bulb temperature exceeded the return air temperature and system moved to the minimum damper position for the experiment and the simulation. During the night, the system relied on the cooler outside air for conditioning the

zones and did not need to use the cooling coils. The statistical comparisons for the “A” system are shown in Table 6.2.3.

Table 6.2.3: Statistical comparisons of the “A” system airflow rates and cooling heat rate.

Statistics	Supply Airflow Rate, m ³ /hr		Outside Airflow Rate, m ³ /hr		Cooling HTR, KW	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	1991.0	2009.3	1788.4	1580.8	2.5	2.1
σ	34.9	NA	6.0	NA	0.7	NA
s	628.4	673.2	862.8	818.8	3.1	3.1
x_{\max}	3129.0	3657.0	3321.0	3285.0	10.4	12.1
x_{\min}	1354.0	1359.0	165.0	139.0	0.1	0.0
\bar{D}	NA	-18.4	NA	207.7	NA	0.4
D_{\max}	NA	696.0	NA	1551.0	NA	2.3
D_{\min}	NA	0.0	NA	7.0	NA	0.0
$ D $	NA	99.0	NA	273.0	NA	0.5
D_{rms}	NA	166.1	NA	345.1	NA	0.7
SE	NA	-0.9	NA	13.1	NA	18.2
IE	NA	4.9	NA	17.3	NA	24.9

The DOE-2.1E simulation predictions for the supply airflow rates were within 5% of the experiment. Larger errors were seen in the outside airflow rate and cooling heat transfer rate comparisons. The average difference between the simulation and the experiment for the supply airflow rate and the cooling heat transfer rate falls within their respective 95% uncertainty bounds, whereas the average difference for the airflow rate does not fall within its 95% uncertainty bounds. The graphical results for the “B” system airflow rates and the cooling heat transfer rate are shown in Figure 6.2.5.

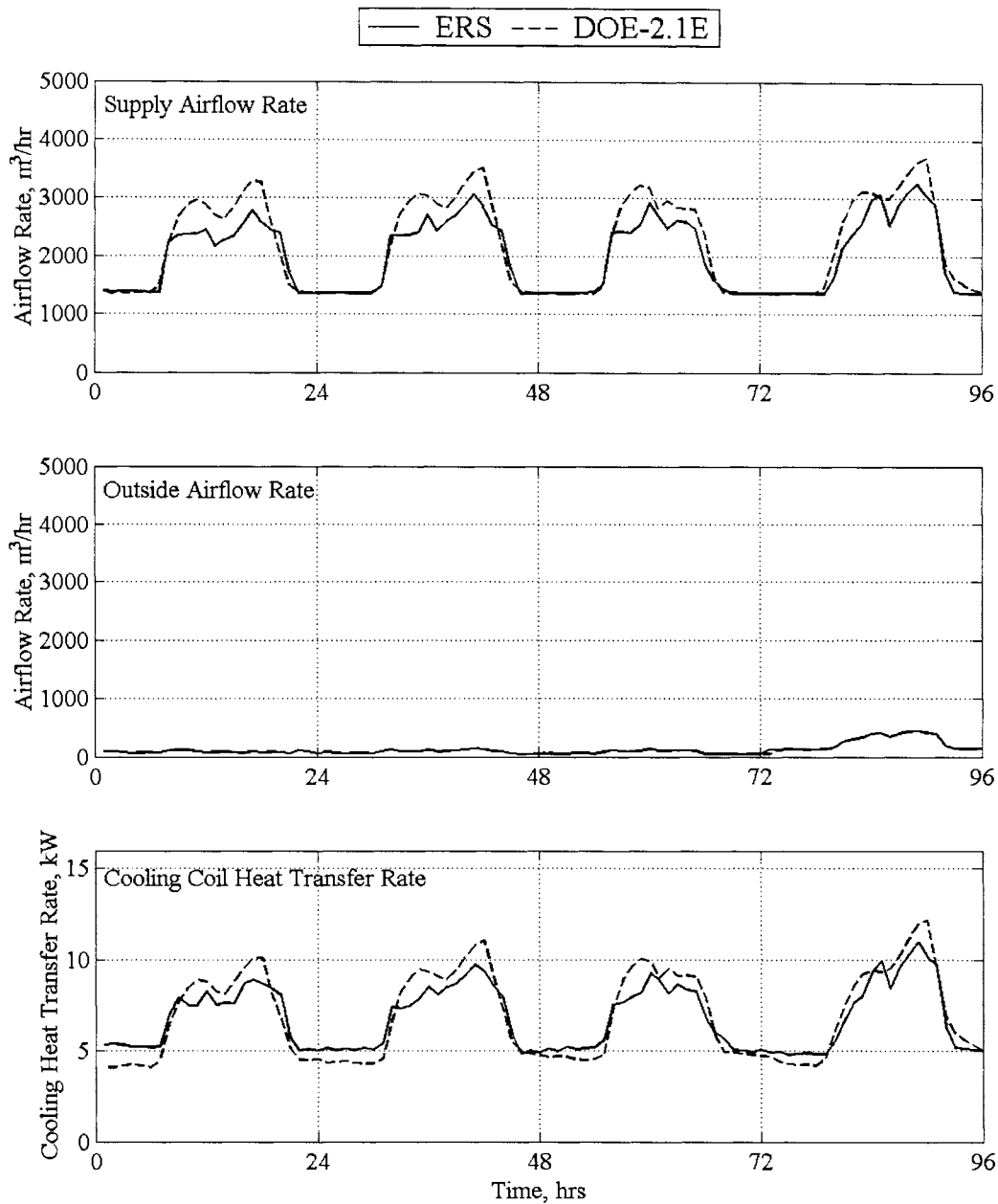


Figure 6.2.5: System “B” airflow rates and cooling coil heat transfer rate comparisons.

The DOE2.1E simulation predictions were not as accurate as the “A” system. The outside airflow rates match up exactly because experimental results were used to schedule hour-by-hour minimum airflow rates. For the cooling heat transfer rate, the DOE-2.1E under-predicts the cooling heat transfer rates at night and over-predicts them during the day. Unlike the “A” system, mechanical cooling was required during the entire test. The statistical comparisons for the “B” system are shown in Table 6.2.4.

Table 6.2.3: Statistical comparisons of the “B” system airflow rates and cooling heat rate.

Statistics	Supply Airflow Rate, m ³ /hr		Outside Airflow Rate, m ³ /hr		Cooling HTR, KW	
	ERS	DOE-2.1E	ERS	DOE-2.1E	ERS	DOE-2.1E
\bar{x}	1985.7	2168.9	126.1	125.9	6.8	6.9
σ	35.3	NA	14.3	NA	0.8	NA
s	620.7	798.2	97.0	97.0	1.8	2.4
x_{\max}	3260.0	3700.0	447.0	446.0	11.0	12.2
x_{\min}	1357.0	1361.0	47.0	47.0	4.8	4.1
\bar{D}	NA	-183.2	NA	0.2	NA	-0.1
D_{\max}	NA	692.0	NA	73.0	NA	2.0
D_{\min}	NA	1.0	NA	0.0	NA	0.0
$ D $	NA	216.8	NA	1.8	NA	0.7
D_{rms}	NA	310.4	NA	8.1	NA	0.9
SE	NA	-8.4	NA	0.1	NA	-1.8
IE	NA	10.0	NA	1.4	NA	10.8

The results seen from the plots are reflected in the statistics. The DOE-2.1E under-predicted the supply airflow rate for the simulation. The supply airflow rates indicated how well the simulation did in predicting the zone loads. Very small discrepancies were seen in the outside airflow rate, but this was a user input and not a predicted parameter. For the cooling coil heat transfer rate, the simulation error was small. Apparently over-predicted cooling heat transfer rate during the day compensated for the under-predicted it at night. The instantaneous error indicates that there were some prediction errors for hour-by-hour results. The average difference between the simulation and the experiment for the outside airflow rate and the cooling heat transfer rate falls within their respective 95% uncertainty bounds from the experiment, whereas the average difference for the airflow rate does not fall with its 95% uncertainty bounds.

There were also some discrepancies between the “A” and the “B” airflow rates may be a result of the psychometric calculations that DOE-2.1E does with the mixed air temperatures. For the experiment, the energy from the water vapor in the air was neglected. DOE-2.1E accounts for the air moisture in its calculation. DOE-2.1E does psychometric calculations to figure out the supply airflow rate, which results in different supply airflow rates for different moisture contents. It would be expected that the moisture content of the supply air for

economizer control would differ from the moisture content when the outside airflow rate was fixed.

6.3 Fixed Damper Position

For a VAV system, a fixed damper position does not necessarily average a percentage of the supply air is from the outside. The minimum outside airflow rate is a function of the pressure drop across the damper. Because of the dynamics associated with VAV system varying the system pressure to adjust the volumes of air entering the respective zones, the pressure throughout the system is not constant or a fixed percentage of the supply air. For a building simulation software package to calculate the minimum outside airflow rate, the duct system, equipment, and dampers would have to be inputted into the simulation and system pressures would need to be calculated across the damper. Currently there are no building simulation software packages robust enough to model the system dynamics.

During the test, the DOE-2.1E model was provided with an hour-by-hour schedule for the outside airflow rate. When using DOE-2.1E to design a building, hour-by-hour outside airflow rate measurements would not be available. Therefore, DOE-2.1E relies on user input for minimum zone ventilation requirements to determine the minimum outside airflow rate. For economizer experiment, it was assumed that the test rooms required enough outdoor ventilation for two occupants; thus for each system, the minimum outside airflow rate was $270 \text{ m}^3/\text{hr}$. Figure 6.3.1 shows the difference between the actual outside airflow rate for the “B” system versus the simulation results for a fixed damper position.

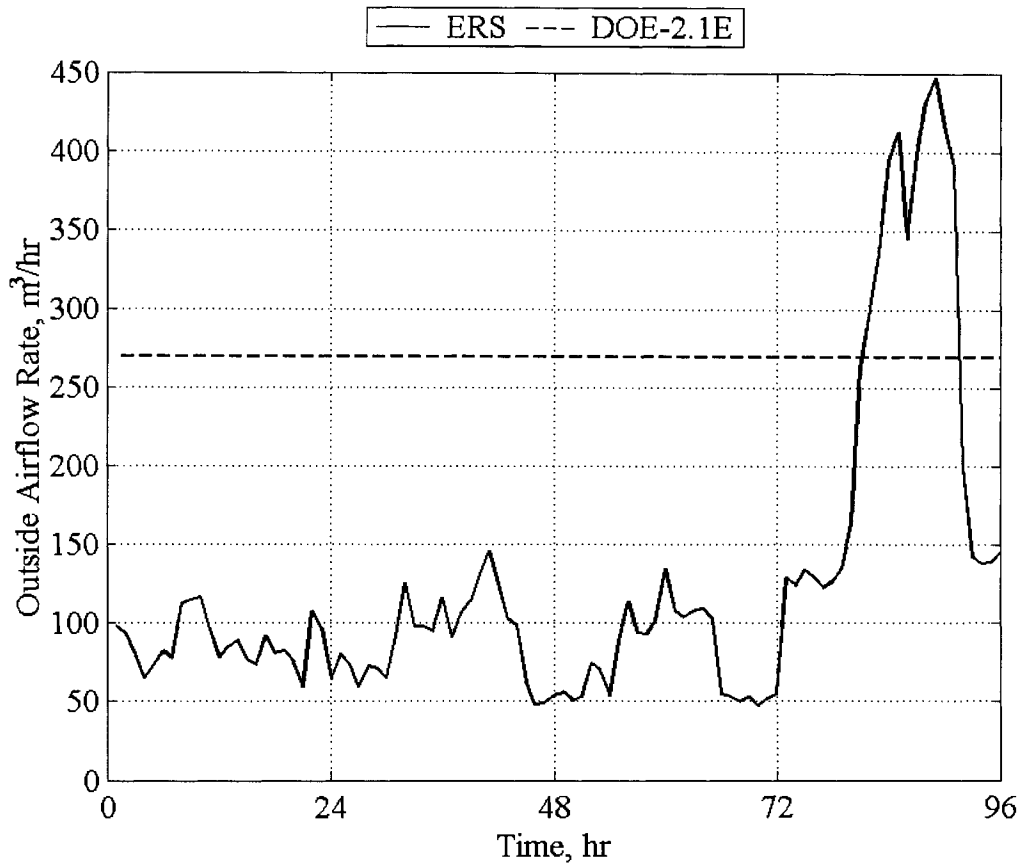


Figure 6.3.1: Simulation and experimental minimum outside airflow rates.

The average outside airflow rate difference was calculated to be $162.8 \text{ m}^3/\text{hr}$. This discrepancy can lead to large errors in the predictions of VAV parameters that use a minimum outside airflow rate. Despite the inconsistencies realized in the outside airflow rate, a fixed outside air damper position is still a common method used to control the minimum outside airflow rate.

Chapter 7: Conclusions and Recommendations

Validation exercises not only test building simulation software, but modelers and facilities. The modeler must be conscience in constructing the simulation software and take full advantage of the robustness of the building simulation software. Small errors in the input may lead to inaccurate predictions that misrepresent the building simulation software, or a modeler may, by default, use simplistic modeling methods that do not fully utilize all the aspects of the software. The modeler is also required to make general assumptions with regard to the zone conditions like the thermal mass. Incorrect estimation of the thermal mass of the space can lead to erroneous zone performance, which affects the system performance. These assumptions can be incorrectly misrepresented as shortcoming in the software.

An additional variable in the validation equation is how well the facility measures the parameters the model predicts. Experimentally uncertainty within measured parameters may make comparison and validation impossible. Many steps have been made at the ERS to provide some assurance that the results are reasonable. Improvements in the temperature calibration procedure and continuous recalibration of the weather station have helped reduce the experimental error. Conscience efforts are made at the ERS to maintain up-to-date documentation with regard to building construction and equipment. These are invaluable aids in the modeling process. Problems in airflow rate measurements, water flow meters, room stratification, and sensor position need to be addressed if these types of validation studies are going to continue to improve.

Results from this research project confirm that DOE-2.1E can simulate both dimmable ballast daylight controls with diffuse window treatments and an economizer control with some degree of accuracy. The comparisons not only revealed discrepancies in the building simulation model, but also in the experiments. Due to the complex nature of the various components of the DOE-2.1E building simulation software, it is difficult to ascertain exactly how inconsistencies and parameters interaction within the software. But the tests did provide a good foundation from which other research can build upon.

7.1 Daylighting Results

The validations for the daylighting test confirmed that by subsidizing artificial light with daylighting, there is a substantial reduction in required light power. Based on the results from this study, DOE-2.1E can estimate the reduction light power for a building with diffuse window treatments within 35%. It was also apparent that DOE-2.1E could not predict the illuminance at the reference point for larger magnitudes of light entering the space. This had very little impact on the light power because for both the simulation and the experiment, the lights were turned off.

The zone airflow rate was indirectly affected by the decrease in the light power. For daylight both daylight tests, the supply airflow rate, which ultimately corresponds to zone cooling, was higher for the “A” system than the “B” system for the simulation and the experiment, which confirms that assumption that cooling load decreases with a dimmable ballast system. The zone airflow rate predictions were within or near the 95% uncertainty bounds. The reduction in cooling was also manifest in the system cooling heat transfer rate. For the both Cases I and II, the heat removed via heat transfer from the “B” airflow was less than that for the “A” airflow.

Because of the zone stratification problems, the simulation software always under-predicted the reheat power required. It was clear that installing ceiling fans did improve the reheat predictions from Case I to Case II. In reality, actual or proposed buildings typically do not use ceiling fans to mix the air in the zone. There are other ways to reduce the stratification problem. The problem could be reduced by using a different type of ceiling diffuser or a fan-powered VAV system. The FPVAV is typically used in perimeter zones of buildings where heating is provided from overhead air distribution. Currently, no building simulation software is robust enough to model the effects of room stratification. This type of analysis would require a computational fluid dynamics (CFD) calculation for each zone. Even with the current computer systems, the computational time required to perform this analysis would make this endeavor unrealistic.

7.2 Economizer Tests

The validations for the economizer facet of the DOE-2.1E lead to some interesting conclusions. When the system was in economizer mode, the building simulation software predicted the outside airflow rate and cooling heat transfer rates within 15% and 20%, respectively. The economizer control scheme predicted when the economizer should be enabled and when it should return to the minimum position. Overall, good results were seen. Perhaps the most interesting result from the economizer validation effort was for the “B” system where the damper position was fixed. The inability of DOE-2.1E to accurately predict the minimum outside airflow rate for a VAV system reveals some of the software’s shortcomings. Obviously, this type of estimation would require intimate knowledge of the building equipment, the duct layout, and the damper interactions. But other detailed inputs are required when constructing a building simulation. Knowledge of the building construction and dimensions are required for the accurate zone load calculation. There are two approaches to dealing with this problem 1.) design a building simulation software with ability to model the dynamics of the duct system, or 2.) construct VAV duct systems with the logic and the capacity to maintain a constant minimum outside airflow rate. As described in the literature review, there are several control strategies used to try to maintain a fixed outside airflow rate. With newer control schemes like demand ventilation, it may become essential for air-handling unit controls to measure and control the outside air. But current control strategies dictate that if building simulation software designers want to simulate reality, and new approach needs to be taken with regard to the minimum outside airflow rate predictions.

7.3 Recommendations

Whole building validation is a wide open field with many opportunities. With new advances in fenestration and new simulation software, daylight and economizer validations are recommended. Energy + is a marriage between Blast and DOE-2.1E and provides an even more power simulation tool. While still in the initial development phase, a unique opportunity is available to perform validations that can impact the development of the

software. The Trane Company has also released Trace 700, which has the ability to create a full year of simulation with TMY weather data.

A more important aspect of the validation process may be the creation of a suit of experiments that can be used to measure any building simulation software for various building control strategies including daylighting and economizer control. Although the validation of specific building simulation software is important, a comprehensive and integrated set of experimental data for empirical validation of tools available to tool authors, researchers, codes and standards organizations.

In conclusion, the results from this research provide a realistic analysis of how difference facets of DOE-2.1E interact with each other. Also from this research, good experimental results are available to validate other building simulation software programs.

Appendix A: DOE-2.1E Input Files

Daylight Case I

```

$ Yearly simulation using DOE2 for ERS at Ankeny, Iowa
$ Schedules used are the typical office building during a year
$ Room B use daylighting (DAYLIGHTING = YES)
$ Comparison for ERH vs HRH
$ Air flow rate with ERH (250,400 CFM) (450,1000 CFM)
$ Fan is on CYCLE-ON-ANY mode
$ Temperature is controlled

$*****
$*****
$                               INPUT FOR ERS LOAD
$
$*****
$*****
INPUT LOADS           INPUT-UNITS = ENGLISH   OUTPUT-UNITS = METRIC ..

TITLE                 LINE-1 *ERS YEARLY ENERGY SIMULATION* ..

ABORT                 IF ERRORS ..

DIAGNOSTIC            WARNINGS      CAUTIONS ..

RUN-PERIOD            APR 18 2002 THRU APR 23 2002 ..

$***** BUILDING DESCRIPTION
$*****
BUILDING-LOCATION LATITUDE = 41.71           LONGITUDE = 93.61
                  ALTITUDE = 0.0           AZIMUTH = 0.0
                  TIME-ZONE = 6             DAYLIGHT-SAVINGS = YES
                  HOLIDAY = NO ..

$***** SCHEDULES FOR TEST ROOMS
$*****

$*** LIGHTING *****
LIGHT-SCH             = SCHEDULE THRU DEC 31
                      (ALL) (1,5) (0) (6,21) (1) (22,24) (0) ..

$*** EQUIPMENT *****
EQP-SCH               = SCHEDULE THRU DEC 31
                      (ALL) (1,8) (0) (9,17) (1) (18,24) (0) ..

$****WINDOW SHADING SCHEDULES
TVIS-SCH-1           = SCHEDULE THRU DEC 31 (ALL) (1,24) (0.56) ..

SC-SCH-1             = SCHEDULE THRU DEC 31 (ALL) (1,24) (0.55) ..

```

\$***** SCHEDULES FOR OTHER ROOMS

ZERO-SCH = SCHEDULE THRU DEC 31 (ALL) (1,24) (0) ..
 PEOPLE-STANDARD = SCHEDULE THRU DEC 31 (ALL) (1,7) (0) (8,18) (1)
 (19,24) (0) ..
 LIGHT-STANDARD = SCHEDULE THRU DEC 31 (ALL) (1,7) (0.05) (8,18) (1)
 (19,24) (0.05) ..
 EQP-STANDARD = SCHEDULE THRU DEC 31 (ALL) (1,7) (0) (8,18) (1)
 (19,24) (0) ..

\$***** MATERIAL DEFINITION

\$** THIS MATERIAL DEFINITION FOR MATERIAL THAT IS NOT AVAILABLE IN DOE2
 DATABASE **

GL1 = MATERIAL
 THICKNESS = 0.0208 CONDUCTIVITY = 0.797
 DENSITY = 138.5 SPECIFIC-HEAT = 0.178 ..

\$***** GLASS TYPES

WINDOW-TEST = GLASS-TYPE
 GLASS-TYPE-CODE = 2866
 FRAME-ABS = 0.7
 FRAME-CONDUCTANCE = 3.037
 SPACER-TYPE-CODE = 1 ..

WINDOW-TYPICAL = GLASS-TYPE
 SHADING-COEF = 0.31 GLASS-CONDUCTANCE = 0.30
 PANES = 2 ..

WINDOW-SKYLITE = GLASS-TYPE
 SHADING-COEF = 0.35 GLASS-CONDUCTANCE = 0.24
 PANES = 1 ..

\$***** LAYERS DEFINITION

SET-DEFAULT FOR LAYERS INSIDE-FILM-RES = 0.68 .. \$ FOR EXTERIOR
 WALLS & ROOFS

\$** ROOF FOR BUILDING EXCEPT THE CLASS ROOMS **

LAY-ROOF = LAYERS MATERIAL =
 (RG02,AR02,IN47,BP01,CC02,AL23,CC02) ..

\$** ROOF FOR CLASS ROOM **

LAY-CLASS-ROOF = LAYERS MATERIAL = (RG02,AR02,IN47,AS01) ..

\$** BOTTOM WALL FOR TEST ROOMS **

LAY-TESTWALL-B = LAYERS MATERIAL = (CC03,IN42,IN43,AL11,BP01,GP02)
 ..

\$** TOP WALL FOR TEST ROOMS **

LAY-TESTWALL-T = LAYERS MATERIAL = (CC04,IN43,AL11,GP02) ..

\$** SPANDREL WALL **

LAY-SPAND-WALL = LAYERS MATERIAL =
(GL1,AL11,GL1,AL31,IN43,IN13,BP01,GP02) ..

\$** OVERHEAD WALL **

LAY-OVH-WALL = LAYERS MATERIAL = (CC04,IN43,AL11,IN13) ..

\$** CLASS ROOMS WALL **

LAY-CLASS-WALL = LAYERS MATERIAL = (CC04,IN43,AL21,IN13,BP01,GP03)
..

\$** BOTTOM WALL FOR BUILDING **

LAY-WALL-B = LAYERS MATERIAL = (CC03,IN43,AL11,IN13,BP01,GP02)
..

\$** TOP WALL FOR BUILDING **

LAY-WALL-T = LAYERS MATERIAL = (CC03,IN43,AL11,IN13,GP02) ..

\$** INTERIOR WALL

LAY-INT-WALL = LAYERS MATERIAL = (GP02,IN13,GP02) ..

\$** CEILING **

LAY-CEILING = LAYERS MATERIAL = (AC03) I-F-R = 0.61 ..

\$** GROUND FLOOR **

LAY-FLOOR = LAYERS MATERIAL = (CC03,CP02) I-F-R = 0.61 ..

**** CONSTRUCTIONS DEFINITION FOR ROOF, WALL, CEILING, PARTITION, FLOOR,
WINDOW AND DOOR *****

\$** ROOF FOR BUILDING EXCEPT CLASS ROOM **

ROOF-STD = CONSTRUCTION
LAYERS = LAY-ROOF
ABSORPTANCE = 0.29 ROUGHNESS = 1 ..

\$** ROOF FOR CLASS ROOM **

ROOF-CLASS = CONSTRUCTION LIKE ROOF-STD
LAYERS = LAY-CLASS-ROOF ..

\$** TEST ROOM BOTTOM WALL **

WALL-TESTROOM-B = CONSTRUCTION
LAYERS = LAY-TESTWALL-B
ABSORPTANCE = 0.69 ROUGHNESS = 3 ..

\$** TEST ROOM TOP WALL **

WALL-TESTROOM-T = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-TESTWALL-T ..

\$** SPANDRELL WALL **

WALL-SPANDRELL = CONSTRUCTION
LAYERS = LAY-SPAND-WALL
ABSORPTANCE = 0.90 ROUGHNESS = 6 ..

```

$** OVERHEAD WALL **
WALL-OVERHEAD      = CONSTRUCTION LIKE WALL-TESTROOM-B
                      LAYERS = LAY-OVH-WALL ..

$** CLASSROOM WALL **
WALL-CLASSROOM     = CONSTRUCTION LIKE WALL-TESTROOM-B
                      LAYERS = LAY-CLASS-WALL ..

$** TYPICAL BUILDING BOTTOM-WALL **
WALL-BOTTOM        = CONSTRUCTION LIKE WALL-TESTROOM-B
                      LAYERS = LAY-WALL-B ..

$** TYPICAL BUILDING TOP-WALL **
WALL-TOP           = CONSTRUCTION LIKE WALL-TESTROOM-B
                      LAYERS = LAY-WALL-T ..

$** INTERIOR WALL FOR SPACE "INTERIOR-WALL" **
INT-WALL           = CONSTRUCTION          LAYERS = LAY-INT-WALL ..

$** INTERIOR WALL FOR INTERIOR ROOMS
WALL-INT           = CONSTRUCTION          U = 0.6 ..

$** CEILING **
CEILING            = CONSTRUCTION          LAYERS = LAY-CEILING ..

$** GROUND FLOOR **
GND-FLOOR          = CONSTRUCTION          LAYERS = LAY-FLOOR ..

$***** SET DEFAULT VALUES *****
SET-DEFAULT FOR WINDOW      X = 0 Y = 3 WIDTH = 14   HEIGHT = 5 ..

SET-DEFAULT FOR ROOF        CONSTRUCTION = ROOF-STD Z = 14
                             AZIMUTH = 180      TILT = 0    G-R = 0 ..

SET-DEFAULT FOR UNDERGROUND-FLOOR
                             CONSTRUCTION = GND-FLOOR
                             U-EFF = 0.05      TILT = 180 ..

SET-DEFAULT FOR INTERIOR-WALL
                             CONSTRUCTION = INT-WALL      TILT = 90 ..

SET-DEFAULT FOR SPACE        AREA = 275 ..

$***** SPACE CONDITIONS *****
$** SPACE CONDITION FOR TEST ROOM **

TEST-ROOM-A              = SPACE-CONDITIONS
                           ZONE-TYPE          = CONDITIONED
                           TEMPERATURE        = (72.5)
                           LIGHTING-SCHEDULE  = LIGHT-SCH
                           LIGHTING-TYPE      = REC-FLUOR-NV
                           LIGHT-TO-SPACE     = 0.8 $ 1
                           LIGHTING-KW        = 0.5

```


LIGHT-RAD-FRAC = (0)
 EQUIP-SCHEDULE = EQP-SCH
 EQUIPMENT-KW = 1
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-WA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 1
 LIGHTING-KW = 0.353
 LIGHT-RAD-FRAC = (0)
 DAYLIGHTING = YES
 LIGHT-REF-POINT1 = (7.5,7.5,2.5)
 MIN-POWER-FRAC = 1.0
 FLOOR-WEIGHT = 0
 EQUIPMENT-KW = 1.78
 EQUIP-SENSIBLE = 1
 EQUIP-SCHEDULE = EQP-SCH ..

TEST-ROOM-WB = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 1
 LIGHTING-KW = 0.3393
 DAYLIGHTING = YES
 LIGHT-REF-POINT1 = (7.5,7.5,2.5)
 LIGHT-SET-POINT1 = 60
 ZONE-FRACTION1 = 1.0
 LIGHT-CTRL-TYPE1 = CONTINUOUS/OFF
 MIN-LIGHT-FRAC = 0.041833
 MIN-POWER-FRAC = 0.25253
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0
 EQUIPMENT-KW = 1.78
 EQUIP-SENSIBLE = 1
 EQUIP-SCHEDULE = EQP-SCH ..

TEST-ROOM-EA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 1
 LIGHTING-KW = 0.3535
 LIGHT-RAD-FRAC = (0)
 DAYLIGHTING = YES
 LIGHT-REF-POINT1 = (7.5,7.5,2.5)
 MIN-POWER-FRAC = 1.0
 FLOOR-WEIGHT = 0
 EQUIPMENT-KW = 1.78
 EQUIP-SENSIBLE = 1

EQUIP-SCHEDULE = EQP-SCH ..

TEST-ROOM-EB = SPACE-CONDITIONS

ZONE-TYPE	=	CONDITIONED
TEMPERATURE	=	(72.5)
LIGHTING-SCHEDULE	=	LIGHT-SCH
LIGHTING-TYPE	=	REC-FLUOR-NV
LIGHT-TO-SPACE	=	1
LIGHTING-KW	=	0.3411
DAYLIGHTING	=	YES
LIGHT-REF-POINT1	=	(7.5,7.5,2.5)
LIGHT-SET-POINT1	=	60
ZONE-FRACTION1	=	1.0
LIGHT-CTRL-TYPE1	=	CONTINUOUS/OFF
MIN-LIGHT-FRAC	=	0.04248
MIN-POWER-FRAC	=	0.261189
LIGHT-RAD-FRAC	=	(0)
FLOOR-WEIGHT	=	0
EQUIPMENT-KW	=	1.77
EQUIP-SENSIBLE	=	1
EQUIP-SCHEDULE	=	EQP-SCH ..

TEST-ROOM-SA = SPACE-CONDITIONS

ZONE-TYPE	=	CONDITIONED
TEMPERATURE	=	(72.5)
LIGHTING-SCHEDULE	=	LIGHT-SCH
LIGHTING-TYPE	=	REC-FLUOR-NV
LIGHT-TO-SPACE	=	1
LIGHTING-KW	=	0.3585
DAYLIGHTING	=	YES
LIGHT-REF-POINT1	=	(7.5,7.5,2.5)
MIN-POWER-FRAC	=	1.0
LIGHT-RAD-FRAC	=	(0)
FLOOR-WEIGHT	=	0
EQUIPMENT-KW	=	1.77
EQUIP-SENSIBLE	=	1
EQUIP-SCHEDULE	=	EQP-SCH ..

TEST-ROOM-SB = SPACE-CONDITIONS

ZONE-TYPE	=	CONDITIONED
TEMPERATURE	=	(72.5)
LIGHTING-SCHEDULE	=	LIGHT-SCH
LIGHTING-TYPE	=	REC-FLUOR-NV
LIGHT-TO-SPACE	=	1
LIGHTING-KW	=	0.3296
DAYLIGHTING	=	YES
LIGHT-REF-POINT1	=	(7.5,7.5,2.5)
LIGHT-SET-POINT1	=	60
ZONE-FRACTION1	=	1.0
LIGHT-CTRL-TYPE1	=	CONTINUOUS/OFF
MIN-POWER-FRAC	=	0.2712
MIN-LIGHT-FRAC	=	0.04215
LIGHT-RAD-FRAC	=	(0)
FLOOR-WEIGHT	=	0
EQUIPMENT-KW	=	1.77

EQUIP-SENSIBLE = 1
 EQUIP-SCHEDULE = EQP-SCH ..

TEST-ROOM-IA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 1
 LIGHTING-KW = 0.3558
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0
 EQUIPMENT-KW = 1.77
 EQUIP-SENSIBLE = 1
 EQUIP-SCHEDULE = EQP-SCH ..

\$ SPACE CONDITION FOR B ROOMS WITH DAYLIGHTING

TEST-ROOM-IB = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 1
 LIGHTING-KW = 0.3580
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0
 EQUIPMENT-KW = 1.80
 EQUIP-SENSIBLE = 1
 EQUIP-SCHEDULE = EQP-SCH ..

*** SPACE CONDITION FOR INTERIOR ROOM **

INT-SC = S-C LIKE TEST-ROOM-A
 EQUIPMENT-KW = 1 ..

*** SPACE CONDITION FOR OTHER ROOMS **

PLENUMS = S-C ZONE-TYPE = PLENUM FLOOR-WEIGHT = 5 ..

\$* BREAK ROOM AND STORAGE ROOM *

BREAKROOM-COND = S-C LIKE TEST-ROOM-A
 P-SCH = ZERO-SCH
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.5 ..

\$* RECEPTION ROOM, MEDIA CENTER *

MEDIAROOM-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 5
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.8 ..

\$* OFFICE *

OFFICE-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 1

L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.5 ..

\$* COMPUTER ROOM AND DISPLAY ROOM *

COMPUTER-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 1
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 1 ..

\$* CLASS ROOM *

CLASS-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD AREA/PERSON = 100
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 1 ..

\$* MECHANICAL ROOM *

MECHANICAL-COND = S-C LIKE TEST-ROOM-A
 PEOPLE-HG-LAT = 205 PEOPLE-HG-SENS = 245
 P-SCH = PEOPLE-STANDARD N-O-P = 1
 TEMPERATURE = (72.5)
 L-SCH = LIGHT-STANDARD L-T = SUS-FLUOR
 LIGHTING-W/SQFT = 2.5
 E-SCH = EQP-STANDARD E-KW = 2 ..

***** SPACE DESCRIPTION OF TEST ROOMS IN ERS *****

** DESCRIPTION OF PLENUM IN EAST-A ROOM **

P-EAST-A = SPACE
 VOLUME = 1512.5 SPACE-CONDITIONS = PLENUMS ..
 PEWL-EAST-A = EXTERIOR-WALL
 X = 69.6 Y = 43.5 Z = 8.5
 AZ = 90 TILT = 90
 HEIGHT = 5.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-T ..
 ROOF-EAST-A = ROOF
 X = 50.3 Y = 43.5
 HEIGHT = 15.5 WIDTH = 17.741 ..
 PIW1-EAST-A = I-W A = 85.25 N-T = P-MED-1 ..
 PIW2-EAST-A = I-W A = 94.58 N-T = P-EAST-B ..
 PIW3-EAST-A = I-W A = 94.58 N-T = P-BREAK ..
 CEIL-EAST-A = I-W A = 275 N-T = EASTROOM-A
 TILT = 180 CONSTRUCTION = CEILING ..

** DESCRIPTION OF PLENUM IN SOUTH-A ROOM **

P-SOUTH-A = SPACE LIKE P-EAST-A ..
 PEWL-SOUTH-A = EXTERIOR-WALL
 X = 19.3 Y = 0 Z = 8.5
 AZ = 180 TILT = 90
 HEIGHT = 5.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-T ..
 ROOF-SOUTH-A = ROOF
 X = 19.3 Y = 0
 HEIGHT = 17.741 WIDTH = 15.5 ..
 PIW1-SOUTH-A = I-W A = 85.25 N-T = P-MED-1 ..

```
PIW2-SOUTH-A      = I-W          A = 94.58    N-T = P-SOUTH-B ..
PIW3-SOUTH-A      = I-W          A = 94.58    N-T = P-COMPUTER ..
CEIL-SOUTH-A      = I-W          A = 275       N-T = SOUTHROOM-A
                  TILT = 180     CONSTRUCTION = CEILING ..
```

\$\$\$ DESCRIPTION OF PLENUM IN WEST-A ROOM \$\$\$

```
P-WEST-A          = SPACE      LIKE P-EAST-A ..
    PEWL-WEST-A   = EXTERIOR-WALL
                    X = 0        Y = 59        Z = 8.5
                    AZ = 270     TILT = 90
                    HEIGHT = 5.5      WIDTH = 15.5
                    CONSTRUCTION = WALL-TESTROOM-T ..
ROOF-WEST-A       = ROOF
                    X = 0        Y = 43.5
                    HEIGHT = 15.5   WIDTH = 17.741 ..
PIW1-WEST-A       = I-W         A = 179.83    N-T = P-MED-1 ..
PIW2-WEST-A       = I-W         A = 94.58     N-T = P-WEST-B ..
CEIL-WEST-A       = I-W         A = 275       N-T = WESTROOM-A
                    TILT = 180    CONSTRUCTION = CEILING ..
```

*** DESCRIPTION OF PLENUM IN INTERIOR-A ROOM ***

```
P-INT-A          = SPACE      LIKE P-EAST-A ..
    ROOF-INT-A   = ROOF
                X = 18.6      Y = 70
                HEIGHT = 17.741 WIDTH = 15.5 ..
PIW1-INT-A       = I-W        A = 85.25     N-T = P-MED-1      ..
PIW2-INT-A       = I-W        A = 94.58     N-T = P-INT-B      ..
PIW3-INT-A       = I-W        A = 94.58     N-T = P-DISPLAY ..
PIW4-INT-A       = I-W        A = 85.25     N-T = MECH-ROOM  ..
CEIL-INT-A       = I-W        A = 275       N-T = INTROOM-A
                TILT = 180    CONSTRUCTION = CEILING ..
```

S** DESCRIPTION OF EAST-A ROOM **

```

EASTROOM-A      = SPACE
                  VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-EA
..
REWL-EAST-A      = EXTERIOR-WALL
                  X = 69.6    Y = 43.5    Z = 0
                  AZ = 90    TILT = 90
                  HEIGHT = 8.5    WIDTH = 15.5
                  CONSTRUCTION = WALL-TESTROOM-B ..
W-1-EAST-A       = WINDOW
                  X= 0.158 Y = 3
                  HEIGHT = 4.95    WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST
                  WIN-SHADE-TYPE = MOVABLE-INTERIOR
                  VIS-TRANS-SCH = TVIS-SCH-1
                  SHADING-SCHEDULE = SC-SCH-1 ..
W-2-EAST-A       = WINDOW
                  X= 3.6 Y = 3
                  HEIGHT = 4.95    WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST

```

WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-3-EAST-A = WINDOW
 X= 7.04 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-4-EAST-A = WINDOW
 X= 10.48 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

RIW1-EAST-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
 CENTER CONS = WALL-INT ..
 RIW2-EAST-A = I-W AREA = 150.8 NEXT-TO = EASTROOM-B
 ..
 RIW3-EAST-A = I-W AREA = 150.8 NEXT-TO = BREAKROOM
 ..
 FLOOR-EAST-A = UNDERGROUND-FLOOR
 H = 15.5 W = 17.741 ..

*** DESCRIPTION OF SOUTH-A ROOM **

SOUTHROOM-A = SPACE
 VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-SA

..

REWL-SOUTH-A = EXTERIOR-WALL
 X = 19.3 Y = 0 Z = 0
 AZ = 180 TILT = 90
 HEIGHT = 8.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-B ..

W-1-SOUTH-A = WINDOW
 X= 0.158 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-2-SOUTH-A = WINDOW
 X= 3.6 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR

VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-3-SOUTH-A = WINDOW
 X= 7.04 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-4-SOUTH-A = WINDOW
 X= 10.48 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

RIW1-SOUTH-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
 CENTER CONS = WALL-INT ..
 RIW2-SOUTH-A = I-W AREA = 150.8 NEXT-TO = SOUTHROOM-
 B ..
 RIW3-SOUTH-A = I-W AREA = 150.8 NEXT-TO = COMPUTER-
 RM ..
 FLOOR-SOUTH-A = UNDERGROUND-FLOOR
 H = 17.741 W = 15.5 ..

*** DESCRIPTION OF WEST-A ROOM **

WESTROOM-A = SPACE
 VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-WA
 ..

REWL-WEST-A = EXTERIOR-WALL
 X = 0 Y = 59 Z = 0
 AZ = 270 TILT = 90
 HEIGHT = 8.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-B ..

W-1-WEST-A = WINDOW
 X= 0.158 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR
 VIS-TRANS-SCH = TVIS-SCH-1
 SHADING-SCHEDULE = SC-SCH-1 ..

W-2-WEST-A = WINDOW
 X= 3.6 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST
 WIN-SHADE-TYPE = MOVABLE-INTERIOR

VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

W-3-WEST-A = WINDOW
X= 7.04 Y = 3
HEIGHT = 4.95 WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

W-4-WEST-A = WINDOW
X= 10.48 Y = 3
HEIGHT = 4.95 WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

RIW1-WEST-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
CENTER CONS = WALL-INT ..
RIW2-WEST-A = I-W AREA = 150.8 NEXT-TO = WESTROOM-B
..
RIW3-WEST-A = I-W AREA = 150.8 NEXT-TO = COMPUTER-
RM ..
FLOOR-WEST-A = UNDERGROUND-FLOOR
H = 15.5 W = 17.741 ..

*** DESCRIPTION OF INTERIOR-A ROOM **

INTROOM-A = SPACE
VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-IA
..
RIW1-INT-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
CENTER CONS = WALL-INT ..
RIW2-INT-A = I-W AREA = 150.8 NEXT-TO = INTROOM-B
..
RIW3-INT-A = I-W AREA = 150.8 NEXT-TO = DISPLAY-RM
..
RIW4-INT-A = I-W AREA = 131.75 NEXT-TO = MECH-ROOM
..
FLOOR-INT-A
= UNDERGROUND-FLOOR
H = 17.741 W = 15.5 U-EFF = 0.005 ..

*** DESCRIPTION OF PLENUM IN EAST-B ROOM **

P-EAST-B = SPACE
VOLUME = 1512.5 SPACE-CONDITIONS = PLENUMS ..
PEWL-EAST-B = EXTERIOR-WALL
X = 69.6 Y = 28 Z = 8.5
AZ = 90 TILT = 90
HEIGHT = 5.5 WIDTH = 15.5
CONSTRUCTION = WALL-TESTROOM-T ..


```

      ROOF-EAST-B      = ROOF
                        X = 50.3      Y = 28
                        HEIGHT = 15.5      WIDTH = 17.741 ..
      PIW1-EAST-B      = I-W      AREA = 85.25      NEXT-TO = P-MED-1 ..
      PIW2-EAST-B      = I-W      AREA = 95.28      NEXT-TO = P-
RECEPTION ..
      CEIL-EAST-B      = I-W      AREA = 275      NEXT-TO = EASTROOM-B
                        TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN SOUTH-B ROOM **

```

P-SOUTH-B      = SPACE      LIKE P-EAST-B ..
      PEWL-SOUTH-B      = EXTERIOR-WALL
                        X = 34.8      Y = 0      Z = 8.5
                        AZ = 180      TILT = 90
                        HEIGHT = 5.5      WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-T ..
      ROOF-SOUTH-B      = ROOF
                        X = 34.8      Y = 0
                        HEIGHT = 17.741      WIDTH = 15.5 ..
      PIW1-SOUTH-B      = I-W      AREA = 85.25      NEXT-TO = P-MED-1 ..
      PIW2-SOUTH-B      = I-W      AREA = 95.28      NEXT-TO = P-OFFICE
..
      CEIL-SOUTH-B      = I-W      AREA = 275      NEXT-TO = SOUTHROOM-
B
                        TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN WEST-B ROOM **

```

P-WEST-B      = SPACE      LIKE P-EAST-B ..
      PEWL-WEST-B      = EXTERIOR-WALL
                        X = 0      Y = 43.5      Z = 8.5
                        AZ = 270      TILT = 90
                        HEIGHT = 5.5      WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-T ..
      ROOF-WEST-B      = ROOF
                        X = 0      Y = 28
                        HEIGHT = 15.5      WIDTH = 17.741 ..
      PIW1-WEST-B      = I-W      AREA = 85.25      NEXT-TO = P-MED-1
..
      PIW2-WEST-B      = I-W      AREA = 95.28      NEXT-TO = P-COMPUTER
..
      CEIL-WEST-B      = I-W      AREA = 275      NEXT-TO = WESTROOM-B
                        TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN INTERIOR-B ROOM **

```

P-INT-B      = SPACE      LIKE P-EAST-B ..
      ROOF-INT-B      = ROOF
                        X = 34.1      Y = 70
                        HEIGHT = 17.741      WIDTH = 15.5 ..
      PIW1-INT-B      = I-W      AREA = 179.83      NEXT-TO = P-MED-1 ..
      PIW2-INT-B      = I-W      AREA = 85.25      NEXT-TO = MECH-ROOM
..
      CEIL-INT-B      = I-W      AREA = 275      NEXT-TO = INTROOM-B

```

H = 15.5 W = 17.741 ..

*** DESCRIPTION OF SOUTH-B ROOM **

```

SOUTHROOM-B          = SPACE
                        VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-SB
..
REWL-SOUTH-B         = EXTERIOR-WALL
                        X = 34.8      Y = 0      Z = 0
                        AZ = 180      TILT = 90
                        HEIGHT = 8.5    WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-B ..
W-1-SOUTH-B          = WINDOW
X= 0.158 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

W-2-SOUTH-B          = WINDOW
X= 3.6 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

W-3-SOUTH-B          = WINDOW
X= 7.04 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

W-4-SOUTH-B          = WINDOW
X= 10.48 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1 ..

RIW1-SOUTH-B         = I-W          AREA = 131.75    NEXT-TO = MEDIA-
CENTER
                        CONSTRUCTION = WALL-INT ..
RIW2-SOUTH-B         = I-W          AREA = 150.8      NEXT-TO = OFFICE  ..
FLOOR-SOUTH-B        = UNDERGROUND-FLOOR
                        H = 17.741  W = 15.5  ..

```

*** DESCRIPTION OF WEST-B ROOM **

```

WESTROOM-B          = SPACE

```

```

VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-WB
..
REWL-WEST-B        = EXTERIOR-WALL
                    X = 0          Y = 43.5      Z = 0
                    AZ = 270       TILT = 90
                    HEIGHT = 8.5    WIDTH = 15.5
                    CONSTRUCTION = WALL-TESTROOM-B ..

W-1-WEST-B         = WINDOW
X= 0.158 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1  ..

W-2-WEST-B         = WINDOW
X= 3.6 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1  ..

W-3-WEST-B         = WINDOW
X= 7.04 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1  ..

W-4-WEST-B         = WINDOW
X= 10.48 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST
WIN-SHADE-TYPE = MOVABLE-INTERIOR
VIS-TRANS-SCH = TVIS-SCH-1
SHADING-SCHEDULE = SC-SCH-1  ..

RIW1-WEST-B        = I-W          AREA = 131.75    NEXT-TO = MEDIA-
CENTER
CONSTRUCTION = WALL-INT ..

RIW2-WEST-B        = I-W          AREA = 150.8      NEXT-TO = COMPUTER-
RM ..

FLOOR-WEST-B       = UNDERGROUND-FLOOR
                    H = 15.5      W = 17.741      ..

$** DESCRIPTION OF INTERIOR-B ROOM **
INTROOM-B          = SPACE
VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-IB
..

```

```

        RIW1-INT-B      = I-W      AREA = 282.55      NEXT-TO = MEDIA-
CENTER
        RIW2-INT-B      = I-W      AREA = 131.75      NEXT-TO = MECH-ROOM
..
        FLOOR-INT-B     = UNDERGROUND-FLOOR
                        H = 17.741  W = 15.5      U-EFF = 0.005 ..

$***** SPACE DESCRIPTION OF OTHER ROOMS IN ERS *****

$** DESCRIPTION OF PLENUM IN BREAK ROOM **
P-BREAK      = SPACE
              V = 2341.8  A = 390.3  SPACE-CONDITIONS = PLENUMS
..
        PEWL-BREAK      = EXTERIOR-WALL
                        X = 69.6    Y = 59      Z = 8
                        AZ = 90      TILT = 90
                        HEIGHT = 6    WIDTH = 36.6
                        CONSTRUCTION = WALL-TOP ..
        ROOF-BREAK      = ROOF
                        X = 58.94    Y = 59
                        HEIGHT = 36.6    WIDTH = 10.66 ..
        PIW1-BREAK      = I-W      AREA = 63.96      NEXT-TO = MECH-ROOM
..
        PIW2-BREAK      = I-W      AREA = 219.6      NEXT-TO = P-MED-1
..
        CEIL-BREAK      = I-W      AREA = 390.3      NEXT-TO = BREAKROOM
                        TILT = 180      CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN RECEPTION AREA **
P-RECEPTION  = SPACE
              V = 1268.48 A = 230.63  SPACE-CONDITIONS = PLENUMS
..
        PEWL-RECEPTION  = EXTERIOR-WALL
                        X = 66.6    Y = 15      Z = 8.5
                        AZ = 90      TILT = 90
                        HEIGHT = 5.5    WIDTH = 13
                        CONSTRUCTION = WALL-OVERHEAD ..
        ROOF-RECEPTION  = ROOF
                        X = 50.3    Y = 15
                        HEIGHT = 13    WIDTH = 17.741 ..
        CEIL-RECEPTION  = I-W      AREA = 230.63      NEXT-TO = RECEPTION-
RM
                        TILT = 180      CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN OFFICE **
P-OFFICE     = SPACE
              V = 1087.8  A = 197.8  SPACE-CONDITIONS = PLENUMS
..
        PEW1-OFFICE     = EXTERIOR-WALL
                        X = 66.6    Y = 3      Z = 8.5
                        AZ = 90      TILT = 90
                        HEIGHT = 5.5    WIDTH = 12.1

```

```

                                CONSTRUCTION = WALL-OVERHEAD ..
PEW2-OFFICE                    = EXTERIOR-WALL
                                X = 34.2      Y = 0          Z = 8.5
                                AZ = 180      TILT = 90
                                HEIGHT = 5.5    WIDTH = 16.4
                                CONSTRUCTION = WALL-OVERHEAD ..
ROOF-OFFICE                    = ROOF
                                X = 50.3      Y = 3
                                HEIGHT = 12.1    WIDTH = 16.4 ..
CEIL-OFFICE                    = I-W          AREA = 197.8    NEXT-TO = OFFICE
                                TILT = 180      CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN COMPUTER ROOM **
P-COMPUTER                     = SPACE
                                V = 2284.3    A = 415.3    SPACE-CONDITIONS = PLENUMS
..
PEW1-CMPTR                     = EXTERIOR-WALL
                                X = 3          Y = 3          Z = 8.5
                                AZ = 180      TILT = 90
                                HEIGHT = 5.5    WIDTH = 16.3
                                CONSTRUCTION = WALL-OVERHEAD ..
PEW2-CMPTR                     = EXTERIOR-WALL
                                X = 3          Y = 28         Z = 8.5
                                AZ = 270      TILT = 90
                                HEIGHT = 5.5    WIDTH = 25.1
                                CONSTRUCTION = WALL-OVERHEAD ..
ROOF-CMPTR                     = ROOF
                                X = 3          Y = 3
                                HEIGHT = 25.1    WIDTH = 16.3 ..
CEIL-CMPTR                     = I-W          AREA = 415.3    NEXT-TO = COMPUTER-
RM
                                TILT = 180      CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN WEST CLASS ROOM **
P-CLASS-W                     = SPACE
                                V = 769.7     A = 769.7     SPACE-CONDITIONS = PLENUMS
..
PEW1-CLASS-W                   = EXTERIOR-WALL
                                X = -22.2     Y = 65          Z = 9
                                AZ = 180      TILT = 90
                                HEIGHT = 1     WIDTH = 22.2
                                CONSTRUCTION = WALL-CLASSROOM ..
PEW2-CLASS-W                   = EXTERIOR-WALL
                                X = -22.2     Y = 99.3        Z = 9
                                AZ = 270      TILT = 90
                                HEIGHT = 1     WIDTH = 34.67
                                CONSTRUCTION = WALL-CLASSROOM ..
PEW3-CLASS-W                   = EXTERIOR-WALL
                                X = 0          Y = 99.3        Z = 9
                                AZ = 0          TILT = 90
                                HEIGHT = 1     WIDTH = 22.2
                                CONSTRUCTION = WALL-CLASSROOM ..
ROOF-CLASS-W                   = ROOF

```

```

X = -22.5      Y = 65
HEIGHT = 34.67  WIDTH = 22.2
CONSTRUCTION = ROOF-CLASS ..
CEIL-CLASS-W   = I-W      AREA = 796.7      NEXT-TO = CLASSROOM-
W
TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN EAST CLASS ROOM **

```

P-CLASS-E      = SPACE
V = 769.7      A = 769.7      SPACE-CONDITIONS = PLENUMS
..

```

```

PEW1-CLASS-E   = EXTERIOR-WALL
X = 91.8      Y = 65      Z = 9
AZ = 180      TILT = 90
HEIGHT = 1     WIDTH = 22.2
CONSTRUCTION = WALL-CLASSROOM ..

```

```

PEW2-CLASS-E   = EXTERIOR-WALL
X = 91.8      Y = 99.3    Z = 9
AZ = 90       TILT = 90
HEIGHT = 1     WIDTH = 34.67
CONSTRUCTION = WALL-CLASSROOM ..

```

```

PEW3-CLASS-E   = EXTERIOR-WALL
X = 69.6      Y = 99.3    Z = 9
AZ = 0        TILT = 90
HEIGHT = 1     WIDTH = 22.2
CONSTRUCTION = WALL-CLASSROOM ..

```

```

ROOF-CLASS-E   = ROOF
X = 91.8      Y = 65
HEIGHT = 34.67  WIDTH = 22.2
CONSTRUCTION = ROOF-CLASS ..

```

```

CEIL-CLASS-E   = I-W      AREA = 796.7      NEXT-TO = CLASSROOM-
E
TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN DISPLAY ROOM **

```

P-DISPLAY      = SPACE
V = 1740.4     A = 316.4     SPACE-CONDITIONS = PLENUMS
..

```

```

PEW1-DISPLAY   = EXTERIOR-WALL
X = 0          Y = 88      Z = 10
AZ = 270      TILT = 90
HEIGHT = 4     WIDTH = 17.741
CONSTRUCTION = WALL-TOP ..

```

```

ROOF-DISPLAY   = ROOF
X = 0          Y = 70
HEIGHT = 17.741  WIDTH = 17.783 ..

```

```

PIWL-DISPLAY   = I-W      AREA = 98.07      NEXT-TO = MECH-ROOM
..

```

```

CEIL-DISPLAY   = I-W      AREA = 316.4      NEXT-TO = DISPLAY-RM
TILT = 180      CONSTRUCTION =

```

CEILING ..

*** DESCRIPTION OF PLENUM IN MEDIA CENTER **

```

P-MED-1          = SPACE
                  V = 7751.6  A = 1824.1  SPACE-CONDITIONS = PLENUMS
..
    PEW1-MED-1    = EXTERIOR-WALL
                  X = 0          Y = 65          Z = 8.5
                  AZ = 270        TILT = 90
                  HEIGHT = 5.5    WIDTH = 6
                  CONSTRUCTION = WALL-TOP ..
    ROOF-MED-1    = ROOF
                  X = 17.75      Y = 17.75
                  HEIGHT = 60.8   WIDTH = 30 ..
    PIW1-MED-1    = I-W          AREA = 33          NEXT-TO = MECH-ROOM
..
    CEIL-MED-1    = I-W          AREA = 1824.1      NEXT-TO = MEDIA-
CENTER
                  TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF BREAK ROOM **

```

BREAKROOM        = SPACE
                  V = 3122.4  A = 390.3  SPACE-CONDITIONS =
BREAKROOM-COND ..
    REWL-BREAK    = EXTERIOR-WALL
                  X = 69.6      Y = 59
                  AZ = 90        TILT = 90
                  HEIGHT = 8     WIDTH = 36.6
                  CONSTRUCTION = WALL-BOTTOM ..
    RIW1-BREAK    = I-W          AREA = 85.28      NEXT-TO = STORAGE-RM
..
    RIW2-BREAK    = I-W          AREA = 292.8      NEXT-TO = MEDIA-
CENTER
..
    FLOOR-BREAK   = U-F          HEIGHT = 36.6     WIDTH = 10.66
..

```

*** DESCRIPTION OF RECEPTION ROOM **

```

RECEPTION-RM     = SPACE
                  V = 1960.36 A = 230.63  SPACE-CONDITIONS =
MEDIAROOM-COND ..
    REWL-RECEPT = EXTERIOR-WALL
                  X = 66.6      Y = 15
                  AZ = 90        TILT = 90
                  HEIGHT = 8.5   WIDTH = 13
                  CONSTRUCTION = WALL-SPANDRELL ..
    WIND-RECEPT = WINDOW      G-T = WINDOW-TYPICAL  H = 5 W = 7.9
..
    RIW1-RECEPT = I-W          AREA = 150.8      NEXT-TO = OFFICE
..
    FLOOR-RECEPT = U-F          HEIGHT = 13       WIDTH = 17.741
..

```

*** DESCRIPTION OF OFFICE **

```

OFFICE           = SPACE
                  V = 1681.2  A = 197.8  SPACE-CONDITIONS = OFFICE-
COND ..
    REW1-OFFICE   = EXTERIOR-WALL

```



```

X = 66.6          Y = 3
AZ = 90           TILT = 90
HEIGHT = 8.5      WIDTH = 12.1
CONSTRUCTION = WALL-SPANDRELL ..
WIN1-OFFICE       = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 11.8
..
REW2-OFFICE       = EXTERIOR-WALL
X = 50.3          Y = 3
AZ = 180          TILT = 90
HEIGHT = 8.5      WIDTH = 16.4
CONSTRUCTION = WALL-SPANDRELL ..
WIN2-OFFICE       = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 15.3
..
FLOOR-OFFICE      = U-F          HEIGHT = 12.1             WIDTH = 16.4
CONS = GND-FLOOR ..

```

*** DESCRIPTION OF COMPUTER ROOM **

```

COMPUTER-RM       = SPACE
V = 3530.3  A = 415.3  SPACE-CONDITIONS =
COMPUTER-COND ..
REW1-COMP         = EXTERIOR-WALL
X = 3             Y = 3
AZ = 180          TILT = 90
HEIGHT = 8.5      WIDTH = 16.3
CONSTRUCTION = WALL-SPANDRELL ..
WIN1-COMP         = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 15.3
..
REW2-COMP         = EXTERIOR-WALL
X = 3             Y = 28
AZ = 270          TILT = 90
HEIGHT = 8.5      WIDTH = 25.1
CONSTRUCTION = WALL-SPANDRELL ..
WIN2-COMP         = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 24
..
RIW1-COMP         = I-W          A = 85      NEXT-TO = DISPLAY-RM
..
FLOOR-COMP        = U-F          HEIGHT = 25.1      WIDTH = 16.3
..

```

*** DESCRIPTION OF WEST CLASSROOM **

```

CLASSROOM-W       = SPACE
V = 3530.3  A = 415.3  SPACE-CONDITIONS = CLASS-
COND ..
REW1-CLASS-W      = EXTERIOR-WALL
X = -22.2         Y = 65
AZ = 180          TILT = 90
HEIGHT = 9        WIDTH = 22.2
CONSTRUCTION = WALL-CLASSROOM ..
WIN1-CLASS-W      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
REW2-CLASS-W      = EXTERIOR-WALL
X = -22.2         Y = 99.3
AZ = 270          TILT = 90
HEIGHT = 9        WIDTH = 34.67
CONSTRUCTION = WALL-CLASSROOM ..

```

```

WIN2-CLASS-W      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 7 ..
REW3-CLASS-W      = EXTERIOR-WALL
                   X = 0                      Y = 99.3
                   AZ = 0                     TILT = 90
                   HEIGHT = 9                 WIDTH = 22.2
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN3-CLASS-W      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
RIW1-CLASS-W      = I-W          A = 85          NEXT-TO = DISPLAY-RM
..
FLOOR-CLASS-W     = U-F          HEIGHT = 34.67     WIDTH = 22.2
..

```

*** DESCRIPTION OF EAST CLASSROOM **

```

CLASSROOM-E       = SPACE
                   V = 3530.3  A = 415.3  SPACE-CONDITIONS = CLASS-
COND ..
REW1-CLASS-E      = EXTERIOR-WALL
                   X = 91.8                Y = 65
                   AZ = 180                TILT = 90
                   HEIGHT = 9              WIDTH = 22.2
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN1-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
REW2-CLASS-E      = EXTERIOR-WALL
                   X = 91.8                Y = 99.3
                   AZ = 90                 TILT = 90
                   HEIGHT = 9              WIDTH = 34.67
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN2-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 7 ..
REW3-CLASS-E      = EXTERIOR-WALL
                   X = 69.6                Y = 99.3
                   AZ = 0                  TILT = 90
                   HEIGHT = 9              WIDTH = 22.2
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN3-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
RIW1-CLASS-E      = I-W          A = 85          NEXT-TO = BREAKROOM      ..
FLOOR-CLASS-E     = U-F          HEIGHT = 34.67     WIDTH = 22.2          ..

```

*** DESCRIPTION OF DISPLAY ROOM **

```

DISPLAY-RM        = SPACE
                   V = 2689.7  A = 316.4  SPACE-CONDITIONS =
COMPUTER-COND ..
RIW1-DISP         = I-W          A = 151.56  NEXT-TO = MECH-ROOM ..
RIW2-DISP         = I-W          A = 150.80  NEXT-TO = P-MED-1 ..
FLOOR-DISP        = U-F          H = 17.741  W = 17.83 ..

```

*** DESCRIPTION OF STORAGE ROOM **

```

STORAGE-RM        = SPACE
                   V = 2689.7  A = 316.4  SPACE-CONDITIONS =
BREAKROOM-COND ..
REW1-STORE        = EXTERIOR-WALL
                   X = 69.6                Y = 95.6
                   AZ = 90                 TILT = 90

```

```

HEIGHT = 8.5          WIDTH = 25.3
CONSTRUCTION = WALL-BOTTOM ..
REW2-STORE           = EXTERIOR-WALL
                      X = 69.6          Y = 118.6
                      AZ = 0            TILT = 90
                      HEIGHT = 8.5      WIDTH = 10.52
                      CONSTRUCTION = WALL-BOTTOM ..
RIW1-STORE           = I-W             A = 215.05  NEXT-TO = MECH-ROOM
..
RIW2-STORE           = I-W             A = 266.1   NEXT-TO = MECH-ROOM
TILT = 0 ..
FLOOR-STORE          = U-F             HEIGHT = 25.3    WIDTH = 10.55 ..

```

*** DESCRIPTION OF MEDIA CENTER ***

```

MEDIA-CENTER          = SPACE
                        V = 19187.4  A = 1924.1  SPACE-CONDITIONS =
MEDIAROOM-COND ..
    REWL-MEDIA        = EXTERIOR-WALL
                        X = 0          Y = 65
                        AZ = 270       TILT = 90
                        HEIGHT = 8.5   WIDTH = 6
                        CONSTRUCTION = WALL-BOTTOM ..
    ROOF-MEDIA        = ROOF          X = 29.8   Y = 38.5   H = 10.5   W
= 10.5 ..
    WIND-MEDIA        = WINDOW
                        X = 0          Y = 0
                        H = 10         W = 10.5
                        G-T = WINDOW-SKYLITE ..
    RIW1-MEDIA        = I-W          A = 51      NEXT-TO = MECH-ROOM ..
    FLOOR-MEDIA       = U-F          HEIGHT = 64.14  WIDTH = 30 ..

```

\$\$\$ DESCRIPTION OF MECHANICAL ROOM \$\$\$

```

MECH-ROOM          = SPACE
                     V = 26159      A = 1764      SPACE-CONDITIONS =
MECHANICAL-COND ..
    REW1-MECH       = EXTERIOR-WALL
                     X = 0           Y = 118.6
                     AZ = 270        TILT = 90
                     HEIGHT = 14     WIDTH = 19.1
                     CONSTRUCTION = WALL-TOP ..
    REW2-MECH       = EXTERIOR-WALL
                     X = 59.1        Y = 118.6
                     AZ = 0          TILT = 90
                     HEIGHT = 14     WIDTH = 57.8
                     CONSTRUCTION = WALL-TOP ..
    REW3-MECH       = EXTERIOR-WALL
                     X = 69.6        Y = 95.6      Z = 8.5
                     AZ = 90         TILT = 90
                     HEIGHT = 5.5    WIDTH = 25.3
                     CONSTRUCTION = WALL-TOP ..
    REW4-MECH       = EXTERIOR-WALL
                     X = 0           Y = 99.3      Z = 10
                     AZ = 270        TILT = 90
                     HEIGHT = 4      WIDTH = 11.3
                     CONSTRUCTION = WALL-TOP ..

```

ROOF-MECH = ROOF X = 0 Y = 88 H = 30.6 W = 66.3

..

FLOOR-MECH = U-F HEIGHT = 30.6 WIDTH = 57.5 ..

***** REPORTS *****

** VERIFICATION AND SUMMARY REPORT **

\$LOADS-REPORT VERIFICATION = (LV-D)
\$ SUMMARY = (LS-C)
\$ REPORT-FREQUENCY = HOURLY
\$ HOURLY-DATA-SAVE = FORMATTED ..

\$ LV-D = DETAILS OF EXTERIOR SURFACE IN THE PROJECT

\$ LS-C = BUILDING PEAK LOAD COMPONENTS

** LOAD HOURLY REPORT **

L-REPORT-SCH = SCHEDULE THRU DEC 31 (ALL) (1,24) (1) ..

RS = R-B V-T = GLOBAL V-L = (4,3,14,15) ..

* REPORT BLOCK FOR SPACE ELECTRIC FROM LIGHT WITH VARIABLE LIST 45

RL-EALO = R-B V-T = EASTROOM-A V-L = (44) ..
RL-EBLO = R-B V-T = EASTROOM-B V-L = (44) ..
RL-IALO = R-B V-T = INTROOM-A V-L = (44) ..
RL-IBLO = R-B V-T = INTROOM-B V-L = (44) ..
RL-SALO = R-B V-T = SOUTHROOM-A V-L = (44) ..
RL-SBLO = R-B V-T = SOUTHROOM-B V-L = (44) ..
RL-WALO = R-B V-T = WESTROOM-A V-L = (44) ..
RL-WBLO = R-B V-T = WESTROOM-B V-L = (44) ..

HOURLY-LOAD0 = HOURLY-REPORT
REPORT-SCHEDULE = L-REPORT-SCH
REPORT-BLOCK = (RL-EALO,RL-EBLO,RL-IALO,RL-IBLO,
RL-SALO,RL-SBLO,RL-WALO,RL-WBLO)
OPTION = PRINT ..

* REPORT BLOCK FOR SPACE ELECTRIC FROM LIGHT WITH VARIABLE LIST 45

RL-EAL = R-B V-T = EASTROOM-A V-L = (45) ..
RL-EBL = R-B V-T = EASTROOM-B V-L = (45) ..
RL-IAL = R-B V-T = INTROOM-A V-L = (45) ..
RL-IBL = R-B V-T = INTROOM-B V-L = (45) ..
RL-SAL = R-B V-T = SOUTHROOM-A V-L = (45) ..
RL-SBL = R-B V-T = SOUTHROOM-B V-L = (45) ..
RL-WAL = R-B V-T = WESTROOM-A V-L = (45) ..
RL-WBL = R-B V-T = WESTROOM-B V-L = (45) ..

HOURLY-LOAD1 = HOURLY-REPORT
REPORT-SCHEDULE = L-REPORT-SCH
REPORT-BLOCK = (RL-EAL,RL-EBL,RL-IAL,RL-IBL,
RL-SAL,RL-SBL,RL-WAL,RL-WBL)

```

                OPTION                = PRINT ..

RL-EALX      = R-B V-T = EASTROOM-A  V-L = (49) ..
RL-EBLX      = R-B V-T = EASTROOM-B  V-L = (49) ..
RL-IALX      = R-B V-T = INTROOM-A   V-L = (49) ..
RL-IBLX      = R-B V-T = INTROOM-B   V-L = (49) ..
RL-SALX      = R-B V-T = SOUTHROOM-A  V-L = (49) ..
RL-SBLX      = R-B V-T = SOUTHROOM-B  V-L = (49) ..
RL-WALX      = R-B V-T = WESTROOM-A   V-L = (49) ..
RL-WBLX      = R-B V-T = WESTROOM-B   V-L = (49) ..

```

```

HOURLY-LOAD2  = HOURLY-REPORT
                REPORT-SCHEDULE      = L-REPORT-SCH
                REPORT-BLOCK          = (RL-EALX,RL-EBLX,RL-IALX,RL-IBLX,
                                         RL-SALX,RL-SBLX,RL-WALX,RL-WBLX)
                OPTION                = PRINT ..

```

```

WEATHER-LOAD  = HOURLY-REPORT
                REPORT-SCHEDULE      = L-REPORT-SCH
                REPORT-BLOCK          = (RS)
                OPTION                = PRINT ..

```

```

END ..
COMPUTE LOADS ..

```

```

$*****
*****

```

```

$                INPUT FOR ERS HVAC SYSTEM
*

```

```

$*****
*****

```

```

INPUT SYSTEMS      INPUT-UNITS = ENGLISH   OUTPUT-UNITS = METRIC ..

```

```

$***** SCHEDULE FOR ZONE TEMPERATURES
*****

```

```

$** HEATING SET POINT **

```

```

HEAT-SPT          = SCHEDULE THRU DEC 31
                   (WD)   (1,7) (72) (8,18) (72) (19,24) (72)
                   (WEH)  (1,24) (71.6) ..

```

```

$** COOLING SET POINT **

```

```

COOL-SPT          = SCHEDULE THRU DEC 31
                   (WD)   (1,7) (73) (8,18) (73) (19,24) (73)
                   (WEH)  (1,24) (73.4) ..

```

```

$***** SCHEDULE FOR SUPPLY FAN
*****

```

```

FAN-SCH           = SCHEDULE THRU DEC 31
                   (WD)   (1,24) (1)
                   (WEH)  (1,24) (1) ..

```

```

$***** SCHEDULE FOR OUTSIDE AIR
*****

```

```

OA-SCH            = SCHEDULE THRU DEC 31

```

(WD) (1,24) (0)
 (WEH) (1,24) (0) ..

\$***** SCHEDULE FOR SYSTEM CONTROL

\$** HEATING SCHEDULE **

HEAT-SCH = SCHEDULE THRU DEC 31
 (WD) (1,24) (1)
 (WEH) (1,24) (1) ..

\$** COOLING SCHEDULE **

COOL-SCH = SCHEDULE THRU DEC 31
 (WD) (1,24) (1)
 (WEH) (1,24) (1) ..

\$***** ZONE CONTROL

ZONE-CTRL = ZONE-CONTROL
 DESIGN-HEAT-T = 71.6
 HEAT-TEMP-SCH = HEAT-SPT
 DESIGN-COOL-T = 73.4
 COOL-TEMP-SCH = COOL-SPT
 THERMOSTAT-TYPE = PROPORTIONAL
 THROTTLING-RANGE = 1.0 ..

\$***** ZONE AIR

ZA-TEST	=	ZONE-AIR	ASSIGNED-CFM	=	1000 ..
ZA-INT	=	ZONE-AIR	ASSIGNED-CFM	=	550 ..
ZA-BREAK	=	ZONE-AIR	ASSIGNED-CFM	=	340 ..
ZA-RECEPT	=	ZONE-AIR	ASSIGNED-CFM	=	530 ..
ZA-OFFICE	=	ZONE-AIR	ASSIGNED-CFM	=	480 ..
ZA-CMPTR	=	ZONE-AIR	ASSIGNED-CFM	=	1500 ..
ZA-CLASS	=	ZONE-AIR	ASSIGNED-CFM	=	1200 ..
ZA-DISPLAY	=	ZONE-AIR	ASSIGNED-CFM	=	1200 ..
ZA-STOR	=	ZONE-AIR	ASSIGNED-CFM	=	170 ..
ZA-MEDIA	=	ZONE-AIR	ASSIGNED-CFM	=	1835 ..
ZA-MECH	=	ZONE-AIR	ASSIGNED-CFM	=	1300 ..

\$***** ZONES OPERATION

\$** TEST ROOMS A **

P-EAST-A	=	ZONE	ZONE-TYPE	=	PLENUM ..
P-SOUTH-A	=	ZONE	ZONE-TYPE	=	PLENUM ..
P-WEST-A	=	ZONE	ZONE-TYPE	=	PLENUM ..
P-INT-A	=	ZONE	ZONE-TYPE	=	PLENUM ..

EASTROOM-A = ZONE

ZONE-TYPE	=	CONDITIONED
ZONE-CONTROL	=	ZONE-CTRL
ZONE-AIR	=	ZA-TEST
MIN-CFM-RATIO	=	0.2
TERMINAL-TYPE	=	SVAV ..

```

SOUTHROOM-A = ZONE      LIKE EASTROOM-A ..
WESTROOM-A   = ZONE      LIKE EASTROOM-A ..
INTROOM-A    = ZONE      LIKE EASTROOM-A   Z-A = ZA-INT
M-C-R        = 0.3636 ..

```

*** TEST ROOMS B **

```

P-EAST-B     = ZONE      ZONE-TYPE = PLENUM ..
P-SOUTH-B    = ZONE      ZONE-TYPE = PLENUM ..
P-WEST-B     = ZONE      ZONE-TYPE = PLENUM ..
P-INT-B      = ZONE      ZONE-TYPE = PLENUM ..

```

```

EASTROOM-B   = ZONE      LIKE EASTROOM-A ..
SOUTHROOM-B  = ZONE      LIKE EASTROOM-A ..
WESTROOM-B   = ZONE      LIKE EASTROOM-A ..
INTROOM-B    = ZONE      LIKE EASTROOM-A
Z-A = ZA-INT
M-C-R        = 0.3636 ..

```

*** OTHER ROOMS IN ERS **

```

P-BREAK      = ZONE      ZONE-TYPE = PLENUM ..
P-RECEPTION  = ZONE      ZONE-TYPE = PLENUM ..
P-OFFICE     = ZONE      ZONE-TYPE = PLENUM ..
P-COMPUTER   = ZONE      ZONE-TYPE = PLENUM ..
P-CLASS-W    = ZONE      ZONE-TYPE = PLENUM ..
P-CLASS-E    = ZONE      ZONE-TYPE = PLENUM ..
P-DISPLAY    = ZONE      ZONE-TYPE = PLENUM ..
P-MED-1      = ZONE      ZONE-TYPE = PLENUM ..

```

```

BREAKROOM    = ZONE      LIKE EASTROOM-A   Z-A = ZA-BREAK   M-C-R =
0.308 ..
RECEPTION-RM = ZONE      LIKE EASTROOM-A   Z-A = ZA-RECEPT M-C-R =
0.113 ..
OFFICE       = ZONE      LIKE EASTROOM-A   Z-A = ZA-OFFICE  M-C-R =
0.063 ..
COMPUTER-RM  = ZONE      LIKE EASTROOM-A   Z-A = ZA-CMPTR   M-C-R =
0.08 ..
CLASSROOM-W  = ZONE      LIKE EASTROOM-A   Z-A = ZA-CLASS   M-C-R =
0.313 ..
CLASSROOM-E  = ZONE      LIKE EASTROOM-A   Z-A = ZA-CLASS   M-C-R =
0.313 ..
DISPLAY-RM   = ZONE      LIKE EASTROOM-A   Z-A = ZA-DISPLAY M-C-R =
0.25 ..
STORAGE-RM   = ZONE      LIKE EASTROOM-A   Z-A = ZA-STOR    M-C-R =
0.0 ..
MEDIA-CENTER = ZONE      LIKE EASTROOM-A   Z-A = ZA-MEDIA   M-C-R =
0.14 ..
MECH-ROOM    = ZONE      LIKE EASTROOM-A   Z-A = ZA-MECH    M-C-R =
0.29 ..

```

***** SYSTEM CONTROL

*** TEST ROOMS SYSTEMS **

```

SC-TEST      = SYSTEM-CONTROL
               MAX-SUPPLY-T      = 92
               MIN-SUPPLY-T      = 61

```

```

HEATING-SCHEDULE = HEAT-SCH
COOLING-SCHEDULE = COOL-SCH
COOL-CONTROL     = CONSTANT
COOL-SET-T       = 45 ..

```

```

SC-MAIN          = SYSTEM-CONTROL
                  MAX-SUPPLY-T      = 130
                  MIN-SUPPLY-T      = 55
                  HEATING-SCHEDULE  = HEAT-SCH
                  COOLING-SCHEDULE  = COOL-SCH
                  COOL-CONTROL      = CONSTANT
                  COOL-SET-T        = 56 ..

```

\$***** SYSTEM AIR

```

SA-TEST          = SYSTEM-AIR
                  OA-CONTROL         = TEMP
                  DUCT-AIR-LOSS      = 0
                  DUCT-DELTA-T      = 1.0 ..

```

```

SA-MAIN          = SYSTEM-AIR
                  OA-CONTROL         = TEMP
                  SUPPLY-CFM         = 6000
                  MIN-OUTSIDE-AIR    = 0.07
                  DUCT-AIR-LOSS      = 0
                  DUCT-DELTA-T      = 0.5 ..

```

\$***** SYSTEM FAN

```

SYSTEM-FAN       = SYSTEM-FANS
                  FAN-SCHEDULE      = FAN-SCH
                  FAN-CONTROL       = INLET
                  SUPPLY-DELTA-T    = 2.5
                  RETURN-DELTA-T   = 1.9
                  NIGHT-CYCLE-CTRL  = CYCLE-ON-ANY ..

```

\$***** SYSTEM TERMINAL

```

ST-TEST          = SYSTEM-TERMINAL    REHEAT-DELTA-T = 45 ..
ST-MAIN          = SYSTEM-TERMINAL    REHEAT-DELTA-T = 75    MIN-CFM-RATIO
= 0.07 ..

```

\$***** SYSTEMS OPERATION

```

AHU-A            = SYSTEM
                  SYSTEM-CONTROL    = SC-TEST
                  SYSTEM-AIR        = SA-TEST
                  SYSTEM-FANS       = SYSTEM-FAN
                  SYSTEM-TERMINAL   = ST-TEST
                  SYSTEM-TYPE       = VAVS
                  PLENUM-NAMES      = (P-EAST-A, P-SOUTH-A, P-WEST-A)

```



```

ZONE-NAMES = (P-EAST-A, P-SOUTH-A, P-WEST-A, P-INT-
A,
EASTROOM-A, SOUTHROOM-A, WESTROOM-
A, INTROOM-A)
ZONE-HEAT-SOURCE = HOT-WATER
RETURN-AIR-PATH = PLENUM-ZONES ..

AHU-B = SYSTEM
SYSTEM-CONTROL = SC-TEST
SYSTEM-AIR = SA-TEST
SYSTEM-FANS = SYSTEM-FAN
SYSTEM-TERMINAL = ST-TEST
SYSTEM-TYPE = VAVS
PLENUM-NAMES = (P-EAST-B, P-SOUTH-B, P-WEST-B)
ZONE-NAMES = (P-EAST-B, P-SOUTH-B, P-WEST-B, P-INT-
B,
EASTROOM-B, SOUTHROOM-B, WESTROOM-
B, INTROOM-B)
ZONE-HEAT-SOURCE = HOT-WATER
RETURN-AIR-PATH = PLENUM-ZONES ..

AHU-MAIN = SYSTEM
SYSTEM-CONTROL = SC-MAIN
SYSTEM-AIR = SA-MAIN
SYSTEM-FANS = SYSTEM-FAN
SYSTEM-TERMINAL = ST-MAIN
SYSTEM-TYPE = VAVS
PLENUM-NAMES = (P-MED-1, P-COMPUTER, P-OFFICE)
ZONE-NAMES = (P-MED-1, P-COMPUTER, P-OFFICE, P-
BREAK, P-RECEPTION,
P-CLASS-W, P-CLASS-E, P-DISPLAY,
MEDIA-CENTER, COMPUTER-
RM, OFFICE, BREAKROOM, RECEPTION-RM,
CLASSROOM-W, CLASSROOM-E, DISPLAY-
RM, MECH-ROOM, STORAGE-RM)
ZONE-HEAT-SOURCE = HOT-WATER
RETURN-AIR-PATH = PLENUM-ZONES ..

$***** PLANT ASSIGNMENT
*****
PLANT-1 = PLANT-ASSIGNMENT
SYSTEM-NAMES = (AHU-MAIN, AHU-A, AHU-B) ..

$***** REPORTS *****
$** VERIFICATION AND SUMMARY REPORT **
$SYSTEMS-REPORT VERIFICATION = (SV-A)
$ SUMMARY = (SS-A, SS-D, SS-L)
$ REPORT-FREQUENCY = HOURLY
$ HOURLY-DATA-SAVE = FORMATTED ..

$ SV-D = SYSTEM DESIGN PARAMETERS
$ SS-A = SYSTEM MONTHLY LOADS SUMMARY
$ SS-B = PLANT MONTHLY LOADS SUMMARY

```

\$ SS-L = FAN ELECTRIC ENERGY

\$\$\$ LOAD HOURLY REPORT **

S-REPORT-SCH = SCHEDULE THRU DEC 31 (ALL) (1,24) (1) ..

\$* REPORT BLOCK FOR ZONE TEMPERATURE, CFM, AND ZONE COIL HEATING WITH
VARIABLE LIST 6,14,32

RS-EA = R-B V-T = EASTROOM-A V-L = (6, 14, 32) ..

RS-SA = R-B V-T = SOUTHROOM-A V-L = (6, 14, 32) ..

RS-WA = R-B V-T = WESTROOM-A V-L = (6, 14, 32) ..

RS-IA = R-B V-T = INTROOM-A V-L = (6, 14, 32) ..

RS-EB = R-B V-T = EASTROOM-B V-L = (6, 14, 32) ..

RS-SB = R-B V-T = SOUTHROOM-B V-L = (6, 14, 32) ..

RS-WB = R-B V-T = WESTROOM-B V-L = (6, 14, 32) ..

RS-IB = R-B V-T = INTROOM-B V-L = (6, 14, 32) .. \$1,6,14,32

RS-EAL = R-B V-T = END-USE V-L = (1) ..

HOURLY-SYSTEMEA = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-EA)
OPTION = PRINT ..

HOURLY-SYSTEMEB = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-EB)
OPTION = PRINT ..

HOURLY-SYSTEMSA = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-SA)
OPTION = PRINT ..

HOURLY-SYSTEMSB = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-SB)
OPTION = PRINT ..

HOURLY-SYSTEMWA = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-WA)
OPTION = PRINT ..

HOURLY-SYSTEMWB = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-WB)
OPTION = PRINT ..

HOURLY-SYSTEMIA = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH
REPORT-BLOCK = (RS-IA)
OPTION = PRINT ..

HOURLY-SYSTEMIB = HOURLY-REPORT
REPORT-SCHEDULE = S-REPORT-SCH

```

REPORT-BLOCK      = (RS-IB)
OPTION            = PRINT ..

```

```

$* REPORT BLOCK FOR AHU CFM,OA RATIO,TOTAL FAN KW,SF-KW,RF-KW,HCOIL-
T,CCOIL-T (17,39,33,49,50,1,2)

```

```

$RS-AB           = R-B V-T = AHU-B           V-L = (17,39,33,49,50,1,2) ..

```

```

$HOURLY-SYSTEM2  = HOURLY-REPORT
$                REPORT-SCHEDULE   = S-REPORT-SCH
$                REPORT-BLOCK      = (RS-AB)
$                OPTION            = PRINT ..

```

```

$* REPORT BLOCK FOR COOLING COIL ENERGY INPUT AND TOTAL ZONE HEATING
ENERGY INPUT (6 & 7)

```

```

RS-SYA           = R-B V-T = AHU-A           V-L = (17,39,3,2,4,6) ..

```

```

RS-SYB           = R-B V-T = AHU-B           V-L = (17,39,3,2,4,6) ..

```

```

HOURLY-SYSTEM3   = HOURLY-REPORT
                  REPORT-SCHEDULE   = S-REPORT-SCH
                  REPORT-BLOCK      = (RS-SYA)
                  OPTION            = PRINT ..

```

```

HOURLY-SYSTEM4   = HOURLY-REPORT
                  REPORT-SCHEDULE   = S-REPORT-SCH
                  REPORT-BLOCK      = (RS-SYB)
                  OPTION            = PRINT ..

```

```

END ..
COMPUTE SYSTEMS ..
STOP ..

```

Economizer Test

\$ Yearly simulation using DOE2 for ERS at Ankeny, Iowa
 \$ Schedules used are the typical office building during a year
 \$ Room B use daylighting (DAYLIGHTING = YES)
 \$ Comparison for ERH vs HRH
 \$ Air flow rate with ERH (250,400 CFM) (200,1000 CFM)
 \$ Fan is on CYCLE-ON-ANY mode
 \$ Temperature is controlled

```

$*****
*****
$                               INPUT FOR ERS LOAD
*
$*****
*****
INPUT LOADS          INPUT-UNITS = ENGLISH   OUTPUT-UNITS = METRIC ..

TITLE                LINE-1 *ERS YEARLY ENERGY SIMULATION* ..

ABORT                IF ERRORS ..

DIAGNOSTIC           WARNINGS    CAUTIONS ..

RUN-PERIOD           MAY 1 2002 THRU MAY 5 2002 ..

$***** BUILDING DESCRIPTION
*****
BUILDING-LOCATION LATITUDE = 41.71          LONGITUDE = 93.61
                  ALTITUDE = 0.0           AZIMUTH = 0.0
                  TIME-ZONE = 6             DAYLIGHT-SAVINGS = YES
                  HOLIDAY = NO ..

$***** SCHEDULES FOR TEST ROOMS
*****
$*** PEOPLE *****
PEOPLE-SCH           = SCHEDULE THRU DEC 31
                      (ALL) (1,8) (0) (9,20) (0) (21,24) (0) ..

$*** LIGHTING *****
LIGHT-SCH             = SCHEDULE THRU DEC 31
                      (ALL) (1,6) (0) (7,18) (1) (19,24) (0) ..

$***** SCHEDULES FOR OTHER ROOMS
*****
ZERO-SCH              = SCHEDULE THRU DEC 31 (ALL) (1,24) (0) ..
PEOPLE-STANDARD        = SCHEDULE THRU DEC 31 (ALL) (1,7) (0) (8,18) (1)
(19,24) (0) ..
LIGHT-STANDARD         = SCHEDULE THRU DEC 31 (ALL) (1,7) (0.05) (8,18) (1)
                      (19,24) (0.05) ..
  
```

EQP-STANDARD = SCHEDULE THRU DEC 31 (ALL) (1,7)(0) (8,18)(1)
 (19,24)(0) ..

***** MATERIAL DEFINITION

*** THIS MATERIAL DEFINITION FOR MATERIAL THAT IS NOT AVAILABLE IN DOE2
 DATABASE **

GL1 = MATERIAL
 THICKNESS = 0.0208 CONDUCTIVITY = 0.797
 DENSITY = 138.5 SPECIFIC-HEAT = 0.178 ..

***** GLASS TYPES

WINDOW-TEST = GLASS-TYPE
 GLASS-TYPE-CODE = 2866
 FRAME-ABS = 0.7
 FRAME-CONDUCTANCE = 3.037
 SPACER-TYPE-CODE = 1 ..

WINDOW-TYPICAL = GLASS-TYPE
 SHADING-COEF = 0.31 GLASS-CONDUCTANCE = 0.30
 PANES = 2 ..

WINDOW-SKYLITE = GLASS-TYPE
 SHADING-COEF = 0.35 GLASS-CONDUCTANCE = 0.24
 PANES = 1 ..

***** LAYERS DEFINITION

SET-DEFAULT FOR LAYERS INSIDE-FILM-RES = 0.68 .. \$ FOR EXTERIOR
 WALLS & ROOFS

*** ROOF FOR BUILDING EXCEPT THE CLASS ROOMS **

LAY-ROOF = LAYERS MATERIAL =
 (RG02,AR02,IN47,BP01,CC02,AL23,CC02) ..

*** ROOF FOR CLASS ROOM **

LAY-CLASS-ROOF = LAYERS MATERIAL = (RG02,AR02,IN47,AS01) ..

*** BOTTOM WALL FOR TEST ROOMS **

LAY-TESTWALL-B = LAYERS MATERIAL = (CC03,IN42,IN43,AL11,BP01,GP02)
 ..

*** TOP WALL FOR TEST ROOMS **

LAY-TESTWALL-T = LAYERS MATERIAL = (CC04,IN43,AL11,GP02) ..

*** SPANDREL WALL **

LAY-SPAND-WALL = LAYERS MATERIAL =
 (GL1,AL11,GL1,AL31,IN43,IN13,BP01,GP02) ..

*** OVERHEAD WALL **

LAY-OVH-WALL = LAYERS MATERIAL = (CC04,IN43,AL11,IN13) ..

*** CLASS ROOMS WALL **

LAY-CLASS-WALL = LAYERS MATERIAL = (CC04,IN43,AL21,IN13,BP01,GP03)
..

*** BOTTOM WALL FOR BUILDING **

LAY-WALL-B = LAYERS MATERIAL = (CC03,IN43,AL11,IN13,BP01,GP02)
..

*** TOP WALL FOR BUILDING **

LAY-WALL-T = LAYERS MATERIAL = (CC03,IN43,AL11,IN13,GP02) ..

*** INTERIOR WALL

LAY-INT-WALL = LAYERS MATERIAL = (GP02,IN13,GP02) ..

*** CEILING **

LAY-CEILING = LAYERS MATERIAL = (AC03) I-F-R = 0.61 ..

*** GROUND FLOOR **

LAY-FLOOR = LAYERS MATERIAL = (CC03,CP02) I-F-R = 0.61 ..

**** CONSTRUCTIONS DEFINITION FOR ROOF, WALL, CEILING, PARTITION, FLOOR, WINDOW AND DOOR *****

*** ROOF FOR BUILDING EXCEPT CLASS ROOM **

ROOF-STD = CONSTRUCTION
LAYERS = LAY-ROOF
ABSORPTANCE = 0.29 ROUGHNESS = 1 ..

*** ROOF FOR CLASS ROOM **

ROOF-CLASS = CONSTRUCTION LIKE ROOF-STD
LAYERS = LAY-CLASS-ROOF ..

*** TEST ROOM BOTTOM WALL **

WALL-TESTROOM-B = CONSTRUCTION
LAYERS = LAY-TESTWALL-B
ABSORPTANCE = 0.69 ROUGHNESS = 3 ..

*** TEST ROOM TOP WALL **

WALL-TESTROOM-T = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-TESTWALL-T ..

*** SPANDRELL WALL **

WALL-SPANDRELL = CONSTRUCTION
LAYERS = LAY-SPAND-WALL
ABSORPTANCE = 0.90 ROUGHNESS = 6 ..

*** OVERHEAD WALL **

WALL-OVERHEAD = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-OVH-WALL ..

*** CLASSROOM WALL **

WALL-CLASSROOM = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-CLASS-WALL ..

*** TYPICAL BUILDING BOTTOM-WALL **

WALL-BOTTOM = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-WALL-B ..

*** TYPICAL BUILDING TOP-WALL **

WALL-TOP = CONSTRUCTION LIKE WALL-TESTROOM-B
LAYERS = LAY-WALL-T ..

*** INTERIOR WALL FOR SPACE "INTERIOR-WALL" **

INT-WALL = CONSTRUCTION LAYERS = LAY-INT-WALL ..

*** INTERIOR WALL FOR INTERIOR ROOMS

WALL-INT = CONSTRUCTION U = 0.6 ..

*** CEILING **

CEILING = CONSTRUCTION LAYERS = LAY-CEILING ..

*** GROUND FLOOR **

GND-FLOOR = CONSTRUCTION LAYERS = LAY-FLOOR ..

***** SET DEFAULT VALUES *****

SET-DEFAULT FOR WINDOW X = 0 Y = 3 WIDTH = 14 HEIGHT = 5 ..

SET-DEFAULT FOR ROOF CONSTRUCTION = ROOF-STD Z = 14
AZIMUTH = 180 TILT = 0 G-R = 0 ..

SET-DEFAULT FOR UNDERGROUND-FLOOR

CONSTRUCTION = GND-FLOOR
U-EFF = 0.05 TILT = 180 ..

SET-DEFAULT FOR INTERIOR-WALL

CONSTRUCTION = INT-WALL TILT = 90 ..

SET-DEFAULT FOR SPACE

AREA = 275 ..

***** SPACE CONDITIONS *****

*** SPACE CONDITION FOR TEST ROOM **

TEST-ROOM-A = SPACE-CONDITIONS

ZONE-TYPE = CONDITIONED
TEMPERATURE = (72.5)
PEOPLE-SCHEDULE = PEOPLE-SCH
AREA/PERSON = 100
PEOPLE-HG-LAT = 205
PEOPLE-HG-SENS = 245
LIGHTING-SCHEDULE = LIGHT-SCH
LIGHTING-TYPE = REC-FLUOR-NV
LIGHT-TO-SPACE = 0.8 \$ 1
LIGHTING-KW = 0.5
LIGHT-RAD-FRAC = (0)
FLOOR-WEIGHT = 20 ..

TEST-ROOM-WA = SPACE-CONDITIONS
 PEOPLE-SCHEDULE = PEOPLE-SCH
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.4635
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-WB = SPACE-CONDITIONS
 PEOPLE-SCHEDULE = PEOPLE-SCH
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.5305
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-EA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.544
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-EB = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.548
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-SA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.5365
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-SB = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)

LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.5435
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

TEST-ROOM-IA = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 PEOPLE-SCHEDULE = PEOPLE-SCH
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.5335
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

\$ SPACE CONDITION FOR B ROOMS WITH DAYLIGHTING

TEST-ROOM-IB = SPACE-CONDITIONS
 ZONE-TYPE = CONDITIONED
 TEMPERATURE = (72.5)
 LIGHTING-SCHEDULE = LIGHT-SCH
 LIGHTING-TYPE = REC-FLUOR-NV
 LIGHT-TO-SPACE = 0.8 \$ 1
 LIGHTING-KW = 0.5355
 LIGHT-RAD-FRAC = (0)
 FLOOR-WEIGHT = 0 ..

*** SPACE CONDITION FOR INTERIOR ROOM **

INT-SC = S-C LIKE TEST-ROOM-A
 EQUIPMENT-KW = 1 ..

*** SPACE CONDITION FOR OTHER ROOMS **

PLENUMS = S-C ZONE-TYPE = PLENUM FLOOR-WEIGHT = 5 ..

\$* BREAK ROOM AND STORAGE ROOM *

BREAKROOM-COND = S-C LIKE TEST-ROOM-A
 P-SCH = ZERO-SCH
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.5 ..

\$* RECEPTION ROOM, MEDIA CENTER *

MEDIAROOM-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 5
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.8 ..

\$* OFFICE *

OFFICE-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 1

L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 0.5 ..

\$* COMPUTER ROOM AND DISPLAY ROOM *

COMPUTER-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD N-O-P = 1
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 1 ..

\$* CLASS ROOM *

CLASS-COND = S-C LIKE TEST-ROOM-A
 P-SCH = PEOPLE-STANDARD AREA/PERSON = 100
 L-SCH = LIGHT-STANDARD L-T = REC-FLUOR-RV
 E-SCH = EQP-STANDARD E-KW = 1 ..

\$* MECHANICAL ROOM *

MECHANICAL-COND = S-C LIKE TEST-ROOM-A
 PEOPLE-HG-LAT = 205 PEOPLE-HG-SENS = 245
 P-SCH = PEOPLE-STANDARD N-O-P = 1
 TEMPERATURE = (72.5)
 L-SCH = LIGHT-STANDARD L-T = SUS-FLUOR
 LIGHTING-W/SQFT = 2.5
 E-SCH = EQP-STANDARD E-KW = 2 ..

***** SPACE DESCRIPTION OF TEST ROOMS IN ERS *****

** DESCRIPTION OF PLENUM IN EAST-A ROOM **

P-EAST-A = SPACE
 VOLUME = 1512.5 SPACE-CONDITIONS = PLENUMS ..
 PEWL-EAST-A = EXTERIOR-WALL
 X = 69.6 Y = 43.5 Z = 8.5
 AZ = 90 TILT = 90
 HEIGHT = 5.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-T ..
 ROOF-EAST-A = ROOF
 X = 50.3 Y = 43.5
 HEIGHT = 15.5 WIDTH = 17.741 ..
 PIW1-EAST-A = I-W A = 85.25 N-T = P-MED-1 ..
 PIW2-EAST-A = I-W A = 94.58 N-T = P-EAST-B ..
 PIW3-EAST-A = I-W A = 94.58 N-T = P-BREAK ..
 CEIL-EAST-A = I-W A = 275 N-T = EASTROOM-A
 TILT = 180 CONSTRUCTION = CEILING ..

** DESCRIPTION OF PLENUM IN SOUTH-A ROOM **

P-SOUTH-A = SPACE LIKE P-EAST-A ..
 PEWL-SOUTH-A = EXTERIOR-WALL
 X = 19.3 Y = 0 Z = 8.5
 AZ = 180 TILT = 90
 HEIGHT = 5.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-T ..
 ROOF-SOUTH-A = ROOF
 X = 19.3 Y = 0
 HEIGHT = 17.741 WIDTH = 15.5 ..
 PIW1-SOUTH-A = I-W A = 85.25 N-T = P-MED-1 ..

```

PIW2-SOUTH-A      = I-W      A = 94.58   N-T = P-SOUTH-B ..
PIW3-SOUTH-A      = I-W      A = 94.58   N-T = P-COMPUTER ..
CEIL-SOUTH-A      = I-W      A = 275     N-T = SOUTHROOM-A
                                TILT = 180   CONSTRUCTION = CEILING ..

```

*** DESCRIPTION OF PLENUM IN WEST-A ROOM **

```

P-WEST-A          = SPACE      LIKE P-EAST-A ..
    PEWL-WEST-A    = EXTERIOR-WALL
                                X = 0        Y = 59        Z = 8.5
                                AZ = 270     TILT = 90
                                HEIGHT = 5.5   WIDTH = 15.5
                                CONSTRUCTION = WALL-TESTROOM-T ..
    ROOF-WEST-A    = ROOF
                                X = 0        Y = 43.5
                                HEIGHT = 15.5   WIDTH = 17.741 ..
    PIW1-WEST-A    = I-W      A = 179.83   N-T = P-MED-1 ..
    PIW2-WEST-A    = I-W      A = 94.58   N-T = P-WEST-B ..
    CEIL-WEST-A    = I-W      A = 275     N-T = WESTROOM-A
                                TILT = 180   CONSTRUCTION = CEILING ..

```

*** DESCRIPTION OF PLENUM IN INTERIOR-A ROOM **

```

P-INT-A          = SPACE      LIKE P-EAST-A ..
    ROOF-INT-A    = ROOF
                                X = 18.6     Y = 70
                                HEIGHT = 17.741   WIDTH = 15.5 ..
    PIW1-INT-A    = I-W      A = 85.25   N-T = P-MED-1 ..
    PIW2-INT-A    = I-W      A = 94.58   N-T = P-INT-B ..
    PIW3-INT-A    = I-W      A = 94.58   N-T = P-DISPLAY ..
    PIW4-INT-A    = I-W      A = 85.25   N-T = MECH-ROOM ..
    CEIL-INT-A    = I-W      A = 275     N-T = INTROOM-A
                                TILT = 180   CONSTRUCTION = CEILING ..

```

*** DESCRIPTION OF EAST-A ROOM **

```

EASTROOM-A       = SPACE
                                VOLUME = 2337.5   SPACE-CONDITIONS = TEST-ROOM-EA
..
    REWL-EAST-A    = EXTERIOR-WALL
                                X = 69.6     Y = 43.5     Z = 0
                                AZ = 90      TILT = 90
                                HEIGHT = 8.5   WIDTH = 15.5
                                CONSTRUCTION = WALL-TESTROOM-B ..
    W-1-EAST-A     = WINDOW
                                X= 0.158 Y = 3
                                HEIGHT = 4.95   WIDTH = 3.28
                                FRAME-WIDTH = 0.158
                                GLASS-TYPE = WINDOW-TEST ..
    W-2-EAST-A     = WINDOW
                                X= 3.6 Y = 3
                                HEIGHT = 4.95   WIDTH = 3.28
                                FRAME-WIDTH = 0.158
                                GLASS-TYPE = WINDOW-TEST ..
    W-3-EAST-A     = WINDOW
                                X= 7.04 Y = 3

```

HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-4-EAST-A = WINDOW
 X= 10.48 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

RIW1-EAST-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
 CENTER CONS = WALL-INT ..
 RIW2-EAST-A = I-W AREA = 150.8 NEXT-TO = EASTROOM-B
 ..
 RIW3-EAST-A = I-W AREA = 150.8 NEXT-TO = BREAKROOM
 ..
 FLOOR-EAST-A = UNDERGROUND-FLOOR
 H = 15.5 W = 17.741 ..

\$** DESCRIPTION OF SOUTH-A ROOM **

SOUTHROOM-A = SPACE
 VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-SA

..

REWL-SOUTH-A = EXTERIOR-WALL
 X = 19.3 Y = 0 Z = 0
 AZ = 180 TILT = 90
 HEIGHT = 8.5 WIDTH = 15.5
 CONSTRUCTION = WALL-TESTROOM-B ..

W-1-SOUTH-A = WINDOW
 X= 0.158 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-2-SOUTH-A = WINDOW
 X= 3.6 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-3-SOUTH-A = WINDOW
 X= 7.04 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-4-SOUTH-A = WINDOW
 X= 10.48 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

RIW1-SOUTH-A = I-W AREA = 131.75 NEXT-TO = MEDIA-
 CENTER CONS = WALL-INT ..
 RIW2-SOUTH-A = I-W AREA = 150.8 NEXT-TO = SOUTHROOM-B
 ..

```

      RIW3-SOUTH-A      = I-W          AREA = 150.8      NEXT-TO = COMPUTER-
RM ..
      FLOOR-SOUTH-A    = UNDERGROUND-FLOOR
                        H = 17.741  W = 15.5  ..

```

*** DESCRIPTION OF WEST-A ROOM **

```

WESTROOM-A      = SPACE
                  VOLUME = 2337.5  SPACE-CONDITIONS = TEST-ROOM-WA
..

```

```

REW1-WEST-A      = EXTERIOR-WALL
                  X = 0          Y = 59          Z = 0
                  AZ = 270      TILT = 90
                  HEIGHT = 8.5   WIDTH = 15.5
                  CONSTRUCTION = WALL-TESTROOM-B ..

```

```

W-1-WEST-A       = WINDOW
                  X= 0.158 Y = 3
                  HEIGHT = 4.95  WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST ..

```

```

W-2-WEST-A       = WINDOW
                  X= 3.6 Y = 3
                  HEIGHT = 4.95  WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST ..

```

```

W-3-WEST-A       = WINDOW
                  X= 7.04 Y = 3
                  HEIGHT = 4.95  WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST ..

```

```

W-4-WEST-A       = WINDOW
                  X= 10.48 Y = 3
                  HEIGHT = 4.95  WIDTH = 3.28
                  FRAME-WIDTH = 0.158
                  GLASS-TYPE = WINDOW-TEST ..

```

```

      RIW1-WEST-A      = I-W          AREA = 131.75      NEXT-TO = MEDIA-
CENTER CONS = WALL-INT ..
      RIW2-WEST-A      = I-W          AREA = 150.8        NEXT-TO = WESTROOM-B
..
      RIW3-WEST-A      = I-W          AREA = 150.8        NEXT-TO = COMPUTER-
RM ..
      FLOOR-WEST-A     = UNDERGROUND-FLOOR
                        H = 15.5    W = 17.741  ..

```

*** DESCRIPTION OF INTERIOR-A ROOM **

```

INTROOM-A      = SPACE
                  VOLUME = 2337.5  SPACE-CONDITIONS = TEST-ROOM-IA
..

```

```

      RIW1-INT-A       = I-W          AREA = 131.75      NEXT-TO = MEDIA-
CENTER CONS = WALL-INT ..
      RIW2-INT-A       = I-W          AREA = 150.8        NEXT-TO = INTROOM-B
..

```


PIW1-WEST-B	= I-W	AREA = 85.25	NEXT-TO = P-MED-1
PIW2-WEST-B	= I-W	AREA = 95.28	NEXT-TO = P-COMPUTER
CEIL-WEST-B	= I-W	AREA = 275	NEXT-TO = WESTROOM-B
		TILT = 180	CONSTRUCTION =

CEILING ..

*** DESCRIPTION OF PLENUM IN INTERIOR-B ROOM ***

```

P-INT-B          = SPACE      LIKE P-EAST-B ..
    ROOF-INT-B    = ROOF
                    X = 34.1      Y = 70
                    HEIGHT = 17.741  WIDTH = 15.5 ..
    PIW1-INT-B    = I-W        AREA = 179.83      NEXT-TO = P-MED-1 ..
    PIW2-INT-B    = I-W        AREA = 85.25        NEXT-TO = MECH-ROOM
..
    CEIL-INT-B    = I-W        AREA = 275          NEXT-TO = INTROOM-B
                    TILT = 180          CONSTRUCTION =

```

CEILING . .

§** DESCRIPTION OF EAST-B ROOM **

EASTROOM-B = SPACE
VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-EB

```

      REWL-EAST-B      = EXTERIOR-WALL
                        X = 69.6      Y = 28      Z = 0
                        AZ = 90      TILT = 90
                        HEIGHT = 8.5      WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-B ..

```

```
W-1-EAST-B          = WINDOW
X= 0.158 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST ..
```

```
W-2-EAST-B          = WINDOW
X= 3.6 Y = 3
HEIGHT = 4.95  WIDTH = 3.28
FRAME-WIDTH = 0.158
GLASS-TYPE = WINDOW-TEST ..
```

```
W-3-EAST-B          = WINDOW
                     X= 7.04 Y = 3
                     HEIGHT = 4.95  WIDTH = 3.28
                     FRAME-WIDTH = 0.158
                     GLASS-TYPE = WINDOW-TEST ..
```

```
W-4-EAST-B          = WINDOW
                     X= 10.48 Y = 3
                     HEIGHT = 4.95  WIDTH = 3.28
                     FRAME-WIDTH = 0.158
                     GLASS-TYPE = WINDOW-TEST ..
```

RIW1-EAST-B = I-W AREA = 131.75 NEXT-TO = MEDIA-
CENTER
CONSTRUCTION = WALL-INT ..

```

      RIW2-EAST-B      = I-W      AREA = 150.8      NEXT-TO = RECEPTION-
RM ..
      FLOOR-EAST-B     = UNDERGROUND-FLOOR
                        H = 15.5      W = 17.741 ..

```

*** DESCRIPTION OF SOUTH-B ROOM **

```

SOUTHROOM-B      = SPACE
                  VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-SB
..
      REWL-SOUTH-B     = EXTERIOR-WALL
                        X = 34.8      Y = 0      Z = 0
                        AZ = 180      TILT = 90
                        HEIGHT = 8.5      WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-B ..
      W-1-SOUTH-B      = WINDOW
                        X= 0.158 Y = 3
                        HEIGHT = 4.95  WIDTH = 3.28
                        FRAME-WIDTH = 0.158
                        GLASS-TYPE = WINDOW-TEST ..
      W-2-SOUTH-B      = WINDOW
                        X= 3.6 Y = 3
                        HEIGHT = 4.95  WIDTH = 3.28
                        FRAME-WIDTH = 0.158
                        GLASS-TYPE = WINDOW-TEST ..
      W-3-SOUTH-B      = WINDOW
                        X= 7.04 Y = 3
                        HEIGHT = 4.95  WIDTH = 3.28
                        FRAME-WIDTH = 0.158
                        GLASS-TYPE = WINDOW-TEST ..
      W-4-SOUTH-B      = WINDOW
                        X= 10.48 Y = 3
                        HEIGHT = 4.95  WIDTH = 3.28
                        FRAME-WIDTH = 0.158
                        GLASS-TYPE = WINDOW-TEST ..
      RIW1-SOUTH-B     = I-W      AREA = 131.75    NEXT-TO = MEDIA-
CENTER
                  CONSTRUCTION = WALL-INT ..
      RIW2-SOUTH-B     = I-W      AREA = 150.8      NEXT-TO = OFFICE ..
      FLOOR-SOUTH-B    = UNDERGROUND-FLOOR
                        H = 17.741  W = 15.5 ..

```

*** DESCRIPTION OF WEST-B ROOM **

```

WESTROOM-B      = SPACE
                  VOLUME = 2337.5    SPACE-CONDITIONS = TEST-ROOM-WB
..
      REWL-WEST-B      = EXTERIOR-WALL
                        X = 0      Y = 43.5      Z = 0
                        AZ = 270      TILT = 90
                        HEIGHT = 8.5      WIDTH = 15.5
                        CONSTRUCTION = WALL-TESTROOM-B ..
      W-1-WEST-B       = WINDOW
                        X= 0.158 Y = 3

```


HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-2-WEST-B = WINDOW
 X= 3.6 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-3-WEST-B = WINDOW
 X= 7.04 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

W-4-WEST-B = WINDOW
 X= 10.48 Y = 3
 HEIGHT = 4.95 WIDTH = 3.28
 FRAME-WIDTH = 0.158
 GLASS-TYPE = WINDOW-TEST ..

RIW1-WEST-B = I-W AREA = 131.75 NEXT-TO = MEDIA-
 CENTER

CONSTRUCTION = WALL-INT ..
 RIW2-WEST-B = I-W AREA = 150.8 NEXT-TO = COMPUTER-
 RM ..

FLOOR-WEST-B = UNDERGROUND-FLOOR
 H = 15.5 W = 17.741 ..

*** DESCRIPTION OF INTERIOR-B ROOM **

INTROOM-B = SPACE
 VOLUME = 2337.5 SPACE-CONDITIONS = TEST-ROOM-IB

..
 RIW1-INT-B = I-W AREA = 282.55 NEXT-TO = MEDIA-
 CENTER

CONSTRUCTION = WALL-INT ..
 RIW2-INT-B = I-W AREA = 131.75 NEXT-TO = MECH-ROOM

..
 FLOOR-INT-B = UNDERGROUND-FLOOR
 H = 17.741 W = 15.5 U-EFF = 0.005 ..

***** SPACE DESCRIPTION OF OTHER ROOMS IN ERS *****

*** DESCRIPTION OF PLENUM IN BREAK ROOM **

P-BREAK = SPACE
 V = 2341.8 A = 390.3 SPACE-CONDITIONS = PLENUMS

..
 PEWL-BREAK = EXTERIOR-WALL
 X = 69.6 Y = 59 Z = 8
 AZ = 90 TILT = 90
 HEIGHT = 6 WIDTH = 36.6
 CONSTRUCTION = WALL-TOP ..

ROOF-BREAK = ROOF
 X = 58.94 Y = 59
 HEIGHT = 36.6 WIDTH = 10.66 ..


```

PEW2-CMPTR      = EXTERIOR-WALL
                  X = 3          Y = 28          Z = 8.5
                  AZ = 270       TILT = 90
                  HEIGHT = 5.5    WIDTH = 25.1
                  CONSTRUCTION = WALL-OVERHEAD ..

ROOF-CMPTR      = ROOF
                  X = 3          Y = 3
                  HEIGHT = 25.1    WIDTH = 16.3    ..

CEIL-CMPTR      = I-W          AREA = 415.3        NEXT-TO = COMPUTER-
RM
                  TILT = 180        CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN WEST CLASS ROOM **
P-CLASS-W      = SPACE
                  V = 769.7    A = 769.7    SPACE-CONDITIONS = PLENUMS
..

PEW1-CLASS-W    = EXTERIOR-WALL
                  X = -22.2      Y = 65        Z = 9
                  AZ = 180       TILT = 90
                  HEIGHT = 1     WIDTH = 22.2
                  CONSTRUCTION = WALL-CLASSROOM ..

PEW2-CLASS-W    = EXTERIOR-WALL
                  X = -22.2      Y = 99.3      Z = 9
                  AZ = 270       TILT = 90
                  HEIGHT = 1     WIDTH = 34.67
                  CONSTRUCTION = WALL-CLASSROOM ..

PEW3-CLASS-W    = EXTERIOR-WALL
                  X = 0          Y = 99.3      Z = 9
                  AZ = 0         TILT = 90
                  HEIGHT = 1     WIDTH = 22.2
                  CONSTRUCTION = WALL-CLASSROOM ..

ROOF-CLASS-W    = ROOF
                  X = -22.5      Y = 65
                  HEIGHT = 34.67  WIDTH = 22.2
                  CONSTRUCTION = ROOF-CLASS ..

CEIL-CLASS-W    = I-W          AREA = 796.7        NEXT-TO = CLASSROOM-
W
                  TILT = 180        CONSTRUCTION =
CEILING ..

$** DESCRIPTION OF PLENUM IN EAST CLASS ROOM **
P-CLASS-E      = SPACE
                  V = 769.7    A = 769.7    SPACE-CONDITIONS = PLENUMS
..

PEW1-CLASS-E    = EXTERIOR-WALL
                  X = 91.8       Y = 65        Z = 9
                  AZ = 180       TILT = 90
                  HEIGHT = 1     WIDTH = 22.2
                  CONSTRUCTION = WALL-CLASSROOM ..

PEW2-CLASS-E    = EXTERIOR-WALL
                  X = 91.8       Y = 99.3      Z = 9
                  AZ = 90        TILT = 90
                  HEIGHT = 1     WIDTH = 34.67
                  CONSTRUCTION = WALL-CLASSROOM ..

```

```

PEW3-CLASS-E      = EXTERIOR-WALL
                   X = 69.6      Y = 99.3      Z = 9
                   AZ = 0        TILT = 90
                   HEIGHT = 1    WIDTH = 22.2
                   CONSTRUCTION = WALL-CLASSROOM ..

ROOF-CLASS-E      = ROOF
                   X = 91.8      Y = 65
                   HEIGHT = 34.67 WIDTH = 22.2
                   CONSTRUCTION = ROOF-CLASS ..

CEIL-CLASS-E      = I-W          AREA = 796.7      NEXT-TO = CLASSROOM-
E
                   TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN DISPLAY ROOM **

```

P-DISPLAY          = SPACE
                   V = 1740.4    A = 316.4    SPACE-CONDITIONS = PLENUMS
..
PEW1-DISPLAY       = EXTERIOR-WALL
                   X = 0          Y = 88      Z = 10
                   AZ = 270      TILT = 90
                   HEIGHT = 4    WIDTH = 17.741
                   CONSTRUCTION = WALL-TOP ..

ROOF-DISPLAY       = ROOF
                   X = 0          Y = 70
                   HEIGHT = 17.741 WIDTH = 17.783 ..

PIWL-DISPLAY       = I-W          AREA = 98.07      NEXT-TO = MECH-ROOM
..
CEIL-DISPLAY       = I-W          AREA = 316.4      NEXT-TO = DISPLAY-RM
                   TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF PLENUM IN MEDIA CENTER **

```

P-MED-1            = SPACE
                   V = 7751.6    A = 1824.1    SPACE-CONDITIONS = PLENUMS
..
PEW1-MED-1         = EXTERIOR-WALL
                   X = 0          Y = 65      Z = 8.5
                   AZ = 270      TILT = 90
                   HEIGHT = 5.5   WIDTH = 6
                   CONSTRUCTION = WALL-TOP ..

ROOF-MED-1         = ROOF
                   X = 17.75     Y = 17.75
                   HEIGHT = 60.8  WIDTH = 30 ..

PIW1-MED-1         = I-W          AREA = 33        NEXT-TO = MECH-ROOM
..
CEIL-MED-1         = I-W          AREA = 1824.1     NEXT-TO = MEDIA-
CENTER
                   TILT = 180      CONSTRUCTION =
CEILING ..

```

*** DESCRIPTION OF BREAK ROOM **

```

BREAKROOM          = SPACE
                   V = 3122.4    A = 390.3    SPACE-CONDITIONS =
BREAKROOM-COND ..

```

```

REWL-BREAK          = EXTERIOR-WALL
                     X = 69.6      Y = 59
                     AZ = 90        TILT = 90
                     HEIGHT = 8     WIDTH = 36.6
                     CONSTRUCTION = WALL-BOTTOM ..
RIW1-BREAK          = I-W          AREA = 85.28      NEXT-TO = STORAGE-RM
..
RIW2-BREAK          = I-W          AREA = 292.8      NEXT-TO = MEDIA-
CENTER              ..
FLOOR-BREAK         = U-F          HEIGHT = 36.6     WIDTH = 10.66
..

```

*** DESCRIPTION OF RECEPTION ROOM **

```

RECEPTION-RM        = SPACE
                     V = 1960.36 A = 230.63  SPACE-CONDITIONS =
MEDIAROOM-COND ..
  REWL-RECEPT      = EXTERIOR-WALL
                     X = 66.6      Y = 15
                     AZ = 90        TILT = 90
                     HEIGHT = 8.5   WIDTH = 13
                     CONSTRUCTION = WALL-SPANDRELL ..
  WIND-RECEPT      = WINDOW      G-T = WINDOW-TYPICAL   H = 5 W = 7.9
..
  RIW1-RECEPT      = I-W          AREA = 150.8      NEXT-TO = OFFICE
..
  FLOOR-RECEPT     = U-F          HEIGHT = 13        WIDTH = 17.741
..

```

*** DESCRIPTION OF OFFICE **

```

OFFICE              = SPACE
                     V = 1681.2  A = 197.8  SPACE-CONDITIONS = OFFICE-
COND ..
  REW1-OFFICE        = EXTERIOR-WALL
                     X = 66.6      Y = 3
                     AZ = 90        TILT = 90
                     HEIGHT = 8.5   WIDTH = 12.1
                     CONSTRUCTION = WALL-SPANDRELL ..
  WIN1-OFFICE        = WINDOW      G-T = WINDOW-TYPICAL   H = 5 W = 11.8
..
  REW2-OFFICE        = EXTERIOR-WALL
                     X = 50.3      Y = 3
                     AZ = 180      TILT = 90
                     HEIGHT = 8.5   WIDTH = 16.4
                     CONSTRUCTION = WALL-SPANDRELL ..
  WIN2-OFFICE        = WINDOW      G-T = WINDOW-TYPICAL   H = 5 W = 15.3
..
  FLOOR-OFFICE       = U-F          HEIGHT = 12.1      WIDTH = 16.4
                     CONS = GND-FLOOR ..

```

*** DESCRIPTION OF COMPUTER ROOM **

```

COMPUTER-RM         = SPACE
                     V = 3530.3  A = 415.3  SPACE-CONDITIONS =
COMPUTER-COND ..
  REW1-COMP          = EXTERIOR-WALL
                     X = 3          Y = 3

```

```

                AZ = 180                TILT = 90
                HEIGHT = 8.5            WIDTH = 16.3
                CONSTRUCTION = WALL-SPANDRELL ..
WIN1-COMP      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 15.3
..
REW2-COMP      = EXTERIOR-WALL
                X = 3                  Y = 28
                AZ = 270                TILT = 90
                HEIGHT = 8.5            WIDTH = 25.1
                CONSTRUCTION = WALL-SPANDRELL ..
WIN2-COMP      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 24
..
RIW1-COMP      = I-W          A = 85          NEXT-TO = DISPLAY-RM
..
FLOOR-COMP     = U-F          HEIGHT = 25.1      WIDTH = 16.3
..

```

*** DESCRIPTION OF WEST CLASSROOM **

```

CLASSROOM-W    = SPACE
                V = 3530.3  A = 415.3  SPACE-CONDITIONS = CLASS-
COND ..
REW1-CLASS-W   = EXTERIOR-WALL
                X = -22.2            Y = 65
                AZ = 180              TILT = 90
                HEIGHT = 9            WIDTH = 22.2
                CONSTRUCTION = WALL-CLASSROOM ..
WIN1-CLASS-W   = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
REW2-CLASS-W   = EXTERIOR-WALL
                X = -22.2            Y = 99.3
                AZ = 270              TILT = 90
                HEIGHT = 9            WIDTH = 34.67
                CONSTRUCTION = WALL-CLASSROOM ..
WIN2-CLASS-W   = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 7 ..
REW3-CLASS-W   = EXTERIOR-WALL
                X = 0                Y = 99.3
                AZ = 0                TILT = 90
                HEIGHT = 9            WIDTH = 22.2
                CONSTRUCTION = WALL-CLASSROOM ..
WIN3-CLASS-W   = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
RIW1-CLASS-W   = I-W          A = 85          NEXT-TO = DISPLAY-RM
..
FLOOR-CLASS-W  = U-F          HEIGHT = 34.67  WIDTH = 22.2
..

```

*** DESCRIPTION OF EAST CLASSROOM **

```

CLASSROOM-E    = SPACE
                V = 3530.3  A = 415.3  SPACE-CONDITIONS = CLASS-
COND ..
REW1-CLASS-E   = EXTERIOR-WALL
                X = 91.8             Y = 65
                AZ = 180              TILT = 90
                HEIGHT = 9            WIDTH = 22.2
                CONSTRUCTION = WALL-CLASSROOM ..

```

```

WIN1-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
REW2-CLASS-E      = EXTERIOR-WALL
                   X = 91.8          Y = 99.3
                   AZ = 90           TILT = 90
                   HEIGHT = 9        WIDTH = 34.67
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN2-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 7 ..
REW3-CLASS-E      = EXTERIOR-WALL
                   X = 69.6          Y = 99.3
                   AZ = 0            TILT = 90
                   HEIGHT = 9        WIDTH = 22.2
                   CONSTRUCTION = WALL-CLASSROOM ..
WIN3-CLASS-E      = WINDOW      G-T = WINDOW-TYPICAL      H = 5 W = 3.5
..
RIW1-CLASS-E      = I-W          A = 85      NEXT-TO = BREAKROOM ..
FLOOR-CLASS-E     = U-F          HEIGHT = 34.67  WIDTH = 22.2 ..

$** DESCRIPTION OF DISPLAY ROOM **
DISPLAY-RM        = SPACE
                  V = 2689.7  A = 316.4  SPACE-CONDITIONS =
COMPUTER-COND ..
  RIW1-DISP        = I-W          A = 151.56  NEXT-TO = MECH-ROOM ..
  RIW2-DISP        = I-W          A = 150.80  NEXT-TO = P-MED-1 ..
  FLOOR-DISP       = U-F          H = 17.741  W = 17.83 ..

$** DESCRIPTION OF STORAGE ROOM **
STORAGE-RM        = SPACE
                  V = 2689.7  A = 316.4  SPACE-CONDITIONS =
BREAKROOM-COND ..
  REW1-STORE       = EXTERIOR-WALL
                   X = 69.6          Y = 95.6
                   AZ = 90           TILT = 90
                   HEIGHT = 8.5      WIDTH = 25.3
                   CONSTRUCTION = WALL-BOTTOM ..
  REW2-STORE       = EXTERIOR-WALL
                   X = 69.6          Y = 118.6
                   AZ = 0            TILT = 90
                   HEIGHT = 8.5      WIDTH = 10.52
                   CONSTRUCTION = WALL-BOTTOM ..
  RIW1-STORE       = I-W          A = 215.05  NEXT-TO = MECH-ROOM
..
  RIW2-STORE       = I-W          A = 266.1   NEXT-TO = MECH-ROOM
  TILT = 0 ..
  FLOOR-STORE      = U-F          HEIGHT = 25.3  WIDTH = 10.55 ..

$** DESCRIPTION OF MEDIA CENTER **
MEDIA-CENTER      = SPACE
                  V = 19187.4 A = 1924.1  SPACE-CONDITIONS =
MEDIAROOM-COND ..
  REWL-MEDIA       = EXTERIOR-WALL
                   X = 0            Y = 65
                   AZ = 270         TILT = 90
                   HEIGHT = 8.5     WIDTH = 6
                   CONSTRUCTION = WALL-BOTTOM ..

```

```

      ROOF-MEDIA      = ROOF      X = 29.8      Y = 38.5      H = 10.5      W
= 10.5 ..
      WIND-MEDIA      = WINDOW
                        X = 0          Y = 0
                        H = 10         W = 10.5
                        G-T = WINDOW-SKYLITE ..
      RIW1-MEDIA      = I-W        A = 51         NEXT-TO = MECH-ROOM ..
      FLOOR-MEDIA     = U-F        HEIGHT = 64.14    WIDTH = 30 ..

$** DESCRIPTION OF MECHANICAL ROOM **
MECH-ROOM            = SPACE
                        V = 26159    A = 1764      SPACE-CONDITIONS =
MECHANICAL-COND ..
      REW1-MECH       = EXTERIOR-WALL
                        X = 0          Y = 118.6
                        AZ = 270       TILT = 90
                        HEIGHT = 14    WIDTH = 19.1
                        CONSTRUCTION = WALL-TOP ..
      REW2-MECH       = EXTERIOR-WALL
                        X = 59.1       Y = 118.6
                        AZ = 0          TILT = 90
                        HEIGHT = 14    WIDTH = 57.8
                        CONSTRUCTION = WALL-TOP ..
      REW3-MECH       = EXTERIOR-WALL
                        X = 69.6       Y = 95.6      Z = 8.5
                        AZ = 90         TILT = 90
                        HEIGHT = 5.5    WIDTH = 25.3
                        CONSTRUCTION = WALL-TOP ..
      REW4-MECH       = EXTERIOR-WALL
                        X = 0          Y = 99.3      Z = 10
                        AZ = 270       TILT = 90
                        HEIGHT = 4      WIDTH = 11.3
                        CONSTRUCTION = WALL-TOP ..
      ROOF-MECH       = ROOF      X = 0 Y = 88      H = 30.6      W = 66.3
..
      FLOOR-MECH      = U-F        HEIGHT = 30.6    WIDTH = 57.5 ..

```

\$***** REPORTS *****

\$** VERIFICATION AND SUMMARY REPORT **

```

$LOADS-REPORT    VERIFICATION    = (LV-D)
$                SUMMARY        = (LS-C)
$                REPORT-FREQUENCY = HOURLY
$                HOURLY-DATA-SAVE = FORMATTED ..

```

\$ LV-D = DETAILS OF EXTERIOR SURFACE IN THE PROJECT

\$ LS-C = BUILDING PEAK LOAD COMPONENTS

\$** LOAD HOURLY REPORT **

L-REPORT-SCH = SCHEDULE THRU DEC 31 (ALL) (1,24) (1) ..

RS = R-B V-T = GLOBAL V-L = (4,3,14,15) ..

\$* REPORT BLOCK FOR SPACE ELECTRIC FROM LIGHT WITH VARIABLE LIST 45

RL-EA = R-B V-T = EASTROOM-A V-L = (15,16,45) ..

RL-SA = R-B V-T = SOUTHROOM-A V-L = (45) ..
 RL-WA = R-B V-T = WESTROOM-A V-L = (45) ..
 RL-IA = R-B V-T = INTROOM-A V-L = (45) ..

RL-EB = R-B V-T = EASTROOM-B V-L = (45) ..
 RL-SB = R-B V-T = SOUTHROOM-B V-L = (45) ..
 RL-WB = R-B V-T = WESTROOM-B V-L = (45) ..
 RL-IB = R-B V-T = INTROOM-B V-L = (45) ..

HOURLY-ALOAD = HOURLY-REPORT
 REPORT-SCHEDULE = L-REPORT-SCH
 REPORT-BLOCK = (RL-EA, RL-SA, RL-WA, RL-IA)
 OPTION = PRINT ..

HOURLY-BLOAD = HOURLY-REPORT
 REPORT-SCHEDULE = L-REPORT-SCH
 REPORT-BLOCK = (RL-EB, RL-SB, RL-WB, RL-IB)
 OPTION = PRINT ..

WEATHER-LOAD = HOURLY-REPORT
 REPORT-SCHEDULE = L-REPORT-SCH
 REPORT-BLOCK = (RS)
 OPTION = PRINT ..

END ..
 COMPUTE LOADS ..

\$*****

\$ INPUT FOR ERS HVAC SYSTEM
 *

\$*****

INPUT SYSTEMS INPUT-UNITS = ENGLISH OUTPUT-UNITS = METRIC ..

\$*** BASEBOARD HEAT SCHEDULE *****

BASEB = RESET-SCHEDULE THRU DEC 31 (ALL) BASE1 ..

BASE1 = DAY-RESET-SCH
 OUTSIDE-HI = 110 OUTSIDE-LO = 100
 SUPPLY-HI = 1 SUPPLY-LO = 0.99 ..

\$***** SCHEDULE FOR ZONE TEMPERATURES

\$** HEATING SET POINT **

HEAT-SPT = SCHEDULE THRU DEC 31
 (WD) (1,7) (72) (8,18) (72) (19,24) (72)
 (WEH) (1,24) (72) ..

\$** COOLING SET POINT **

COOL-SPT = SCHEDULE THRU DEC 31

(WD) (1,7) (73) (8,18) (73) (19,24) (73)
 (WEH) (1,24) (73) ..

\$***** SCHEDULE FOR SUPPLY FAN

FAN-SCH = SCHEDULE THRU DEC 31
 (WD) (1,7) (1) (8,18) (1) (19,24) (1)
 (WEH) (1,24) (1) ..

\$***** SCHEDULE FOR OUTSIDE AIR

OA-SCH = SCHEDULE THRU DEC 31
 (WD) (1,24) (1)
 (WEH) (1,24) (1) ..

\$***** SCHEDULE FOR OUTSIDE AIR

OA-SCH1 = SCHEDULE THRU DEC 31
 (WD) (1,24) (0.055)
 (WEH) (1,24) (0.055) ..

\$***** SCHEDULE FOR MINIMUM OUTSIDE AIR

OA-M-SCH = SCHEDULE THRU MAY 2 (ALL)
 (1) (0.0170)
 (2) (0.0162)
 (3) (0.0138)
 (4) (0.0113)
 (5) (0.0127)
 (6) (0.0142)
 (7) (0.0136)
 (8) (0.0196)
 (9) (0.0199)
 (10) (0.0203)
 (11) (0.0166)
 (12) (0.0135)
 (13) (0.0147)
 (14) (0.0154)
 (15) (0.0132)
 (16) (0.0128)
 (17) (0.0159)
 (18) (0.0140)
 (19) (0.0144)
 (20) (0.0129)
 (21) (0.0102)
 (22) (0.0187)
 (23) (0.0168)
 (24) (0.0110)
 THRU MAY 3 (ALL)
 (1) (0.0139)
 (2) (0.0128)
 (3) (0.0103)
 (4) (0.0126)
 (5) (0.0122)

(6) (0.0112)
(7) (0.0160)
(8) (0.0219)
(9) (0.0170)
(10) (0.0169)
(11) (0.0164)
(12) (0.0203)
(13) (0.0158)
(14) (0.0183)
(15) (0.0197)
(16) (0.0227)
(17) (0.0253)
(18) (0.0219)
(19) (0.0178)
(20) (0.0171)
(21) (0.0110)
(22) (0.0083)
(23) (0.0085)
(24) (0.0093)

THRU MAY 4 (ALL)

(1) (0.0097)
(2) (0.0088)
(3) (0.0092)
(4) (0.0129)
(5) (0.0122)
(6) (0.0094)
(7) (0.0155)
(8) (0.0197)
(9) (0.0163)
(10) (0.0160)
(11) (0.0176)
(12) (0.0234)
(13) (0.0188)
(14) (0.0181)
(15) (0.0186)
(16) (0.0191)
(17) (0.0178)
(18) (0.0096)
(19) (0.0093)
(20) (0.0087)
(21) (0.0092)
(22) (0.0081)
(23) (0.0090)
(24) (0.0095)

THRU MAY 5 (ALL)

(1) (0.0224)
(2) (0.0214)
(3) (0.0232)
(4) (0.0224)
(5) (0.0212)
(6) (0.0219)
(7) (0.0234)
(8) (0.0284)
(9) (0.0455)
(10) (0.0521)

(11) (0.0582)
 (12) (0.0684)
 (13) (0.0714)
 (14) (0.0597)
 (15) (0.0691)
 (16) (0.0748)
 (17) (0.0774)
 (18) (0.0723)
 (19) (0.0677)
 (20) (0.0347)
 (21) (0.0246)
 (22) (0.0240)
 (23) (0.0241)
 (24) (0.0250)

..
 \$***** SCHEDULE FOR SYSTEM CONTROL

\$** HEATING SCHEDULE **

HEAT-SCH = SCHEDULE THRU DEC 31
 (WD) (1,24) (1)
 (WEH) (1,24) (1) ..

\$** COOLING SCHEDULE **

COOL-SCH = SCHEDULE THRU DEC 31
 (WD) (1,24) (1)
 (WEH) (1,24) (1) ..

\$***** CONTROL

ZONE-CTRL = ZONE-CONTROL
 DESIGN-HEAT-T = 72
 HEAT-TEMP-SCH = HEAT-SPT
 DESIGN-COOL-T = 73
 COOL-TEMP-SCH = COOL-SPT
 THERMOSTAT-TYPE = PROPORTIONAL
 THROTTLING-RANGE = 2.0 ..

\$***** ZONE AIR

ZA-TEST	=	ZONE-AIR	ASSIGNED-CFM	=	1000 ..
ZA-INT	=	ZONE-AIR	ASSIGNED-CFM	=	400 ..
ZA-BREAK	=	ZONE-AIR	ASSIGNED-CFM	=	340 ..
ZA-RECEPT	=	ZONE-AIR	ASSIGNED-CFM	=	530 ..
ZA-OFFICE	=	ZONE-AIR	ASSIGNED-CFM	=	480 ..
ZA-CMPTR	=	ZONE-AIR	ASSIGNED-CFM	=	1500 ..
ZA-CLASS	=	ZONE-AIR	ASSIGNED-CFM	=	1200 ..
ZA-DISPLAY	=	ZONE-AIR	ASSIGNED-CFM	=	1200 ..
ZA-STOR	=	ZONE-AIR	ASSIGNED-CFM	=	170 ..
ZA-MEDIA	=	ZONE-AIR	ASSIGNED-CFM	=	1835 ..
ZA-MECH	=	ZONE-AIR	ASSIGNED-CFM	=	1300 ..

\$***** ZONES OPERATION

\$** TEST ROOMS A **

P-EAST-A = ZONE ZONE-TYPE = PLENUM ..
 P-SOUTH-A = ZONE ZONE-TYPE = PLENUM ..
 P-WEST-A = ZONE ZONE-TYPE = PLENUM ..
 P-INT-A = ZONE ZONE-TYPE = PLENUM ..

EASTROOM-A = ZONE
 ZONE-TYPE = CONDITIONED
 ZONE-CONTROL = ZONE-CTRL
 ZONE-AIR = ZA-TEST
 MIN-CFM-RATIO = 0.2
 TERMINAL-TYPE = SVAV
 BASEBOARD-RATING = -3036.68 ..

SOUTHROOM-A = ZONE LIKE EASTROOM-A BASEBOARD-RATING = -3036.68 ..
 WESTROOM-A = ZONE LIKE EASTROOM-A BASEBOARD-RATING = -2934.32 ..
 INTROOM-A = ZONE LIKE EASTROOM-A Z-A = ZA-INT
 M-C-R = 0.5
 BASEBOARD-RATING = -2968.44 ..

\$** TEST ROOMS B **

P-EAST-B = ZONE ZONE-TYPE = PLENUM ..
 P-SOUTH-B = ZONE ZONE-TYPE = PLENUM ..
 P-WEST-B = ZONE ZONE-TYPE = PLENUM ..
 P-INT-B = ZONE ZONE-TYPE = PLENUM ..

EASTROOM-B = ZONE LIKE EASTROOM-A BASEBOARD-RATING = -3036.68 ..
 SOUTHROOM-B = ZONE LIKE EASTROOM-A BASEBOARD-RATING = -3002.56 ..
 WESTROOM-B = ZONE LIKE EASTROOM-A BASEBOARD-RATING = -3036.68 ..
 INTROOM-B = ZONE LIKE EASTROOM-A
 Z-A = ZA-INT
 M-C-R = 0.5
 BASEBOARD-RATING = -3070.8 ..

\$** OTHER ROOMS IN ERS **

P-BREAK = ZONE ZONE-TYPE = PLENUM ..
 P-RECEPTION = ZONE ZONE-TYPE = PLENUM ..
 P-OFFICE = ZONE ZONE-TYPE = PLENUM ..
 P-COMPUTER = ZONE ZONE-TYPE = PLENUM ..
 P-CLASS-W = ZONE ZONE-TYPE = PLENUM ..
 P-CLASS-E = ZONE ZONE-TYPE = PLENUM ..
 P-DISPLAY = ZONE ZONE-TYPE = PLENUM ..
 P-MED-1 = ZONE ZONE-TYPE = PLENUM ..

BREAKROOM = ZONE LIKE EASTROOM-A Z-A = ZA-BREAK M-C-R =
 0.308 ..
 RECEPTION-RM = ZONE LIKE EASTROOM-A Z-A = ZA-RECEPT M-C-R =
 0.113 ..
 OFFICE = ZONE LIKE EASTROOM-A Z-A = ZA-OFFICE M-C-R =
 0.063 ..
 COMPUTER-RM = ZONE LIKE EASTROOM-A Z-A = ZA-CMPTR M-C-R =
 0.08 ..
 CLASSROOM-W = ZONE LIKE EASTROOM-A Z-A = ZA-CLASS M-C-R =
 0.313 ..
 CLASSROOM-E = ZONE LIKE EASTROOM-A Z-A = ZA-CLASS M-C-R =
 0.313 ..

DISPLAY-RM	=	ZONE	LIKE EASTROOM-A	Z-A = ZA-DISPLAY	M-C-R =
0.25 ..					
STORAGE-RM	=	ZONE	LIKE EASTROOM-A	Z-A = ZA-STOR	M-C-R =
0.0 ..					
MEDIA-CENTER	=	ZONE	LIKE EASTROOM-A	Z-A = ZA-MEDIA	M-C-R =
0.14 ..					
MECH-ROOM	=	ZONE	LIKE EASTROOM-A	Z-A = ZA-MECH	M-C-R =
0.29 ..					

\$***** SYSTEM CONTROL

\$** TEST ROOMS SYSTEMS **

SC-TEST	=	SYSTEM-CONTROL	
		BASEBOARD-SCH	= BASEB
		MAX-SUPPLY-T	= 90
		MIN-SUPPLY-T	= 61.
		HEATING-SCHEDULE	= HEAT-SCH
		COOLING-SCHEDULE	= COOL-SCH
		COOL-CONTROL	= CONSTANT
		COOL-SET-T	= 45 ..

SC-MAIN	=	SYSTEM-CONTROL	
		MAX-SUPPLY-T	= 130
		MIN-SUPPLY-T	= 55
		HEATING-SCHEDULE	= HEAT-SCH
		COOLING-SCHEDULE	= COOL-SCH
		COOL-CONTROL	= CONSTANT
		COOL-SET-T	= 56 ..

\$***** SYSTEM AIR

SA-TEST	=	SYSTEM-AIR	
		OA-CONTROL	= TEMP
		DUCT-AIR-LOSS	= 0
		DUCT-DELTA-T	= 1.0
		M-A-SCH	= OA-M-SCH ..

SB-TEST	=	SYSTEM-AIR	
		OA-CONTROL	= FIXED
		DUCT-AIR-LOSS	= 0
		DUCT-DELTA-T	= 1.0
		M-A-SCH	= OA-M-SCH ..

SA-MAIN	=	SYSTEM-AIR	
		OA-CONTROL	= TEMP
		SUPPLY-CFM	= 6000
		MIN-OUTSIDE-AIR	= 0.07
		DUCT-AIR-LOSS	= 0
		DUCT-DELTA-T	= 0.5 ..

\$***** SYSTEM FAN

```

SYSTEM-FAN  = SYSTEM-FANS
              FAN-SCHEDULE      = FAN-SCH
              FAN-CONTROL        = INLET
              SUPPLY-DELTA-T     = 2.5
              RETURN-DELTA-T    = 1.9
              NIGHT-CYCLE-CTRL   = CYCLE-ON-ANY ..

```

\$***** SYSTEM TERMINAL

```

ST-TEST      = SYSTEM-TERMINAL      REHEAT-DELTA-T = 25 ..
ST-MAIN      = SYSTEM-TERMINAL      REHEAT-DELTA-T = 75 ..

```

\$***** SYSTEMS OPERATION

```

AHU-A        = SYSTEM
              SYSTEM-CONTROL      = SC-TEST
              SYSTEM-AIR          = SA-TEST
              SYSTEM-FANS         = SYSTEM-FAN
              SYSTEM-TERMINAL     = ST-TEST
              SYSTEM-TYPE         = VAVS
              PLENUM-NAMES        = (P-EAST-A, P-SOUTH-A, P-WEST-A)
              ZONE-NAMES          = (P-EAST-A, P-SOUTH-A, P-WEST-A, P-INT-

```

A,

EASTROOM-A, SOUTHROOM-A, WESTROOM-

A, INTROOM-A)

```

              ZONE-HEAT-SOURCE    = HOT-WATER
              RETURN-AIR-PATH      = PLENUM-ZONES ..

```

```

AHU-B        = SYSTEM

```

```

              SYSTEM-CONTROL      = SC-TEST
              SYSTEM-AIR          = SB-TEST
              SYSTEM-FANS         = SYSTEM-FAN
              SYSTEM-TERMINAL     = ST-TEST
              SYSTEM-TYPE         = VAVS
              PLENUM-NAMES        = (P-EAST-B, P-SOUTH-B, P-WEST-B)
              ZONE-NAMES          = (P-EAST-B, P-SOUTH-B, P-WEST-B, P-INT-

```

B,

EASTROOM-B, SOUTHROOM-B, WESTROOM-

B, INTROOM-B)

```

              ZONE-HEAT-SOURCE    = HOT-WATER
              RETURN-AIR-PATH      = PLENUM-ZONES ..

```

```

AHU-MAIN     = SYSTEM

```

```

              SYSTEM-CONTROL      = SC-MAIN
              SYSTEM-AIR          = SA-MAIN
              SYSTEM-FANS         = SYSTEM-FAN
              SYSTEM-TERMINAL     = ST-MAIN
              SYSTEM-TYPE         = VAVS
              PLENUM-NAMES        = (P-MED-1, P-COMPUTER, P-OFFICE)
              ZONE-NAMES          = (P-MED-1, P-COMPUTER, P-OFFICE, P-

```

BREAK, P-RECEPTION,

P-CLASS-W, P-CLASS-E, P-DISPLAY,

RM, OFFICE, BREAKROOM, RECEPTION-RM, MEDIA-CENTER, COMPUTER-
 RM, MECH-ROOM, STORAGE-RM) CLASSROOM-W, CLASSROOM-E, DISPLAY-

ZONE-HEAT-SOURCE = HOT-WATER
 RETURN-AIR-PATH = PLENUM-ZONES ..

\$***** PLANT ASSIGNMENT

PLANT-1 = PLANT-ASSIGNMENT
 SYSTEM-NAMES = (AHU-MAIN, AHU-A, AHU-B) ..

\$***** REPORTS *****

\$** VERIFICATION AND SUMMARY REPORT **

\$SYSTEMS-REPORT VERIFICATION = (SV-A)
 \$ SUMMARY = (SS-A, SS-D, SS-L)
 \$ REPORT-FREQUENCY = HOURLY
 \$ HOURLY-DATA-SAVE = FORMATTED ..

\$ SV-D = SYSTEM DESIGN PARAMETERS
 \$ SS-A = SYSTEM MONTHLY LOADS SUMMARY
 \$ SS-B = PLANT MONTHLY LOADS SUMMARY
 \$ SS-L = FAN ELECTRIC ENERGY

\$** LOAD HOURLY REPORT **

S-REPORT-SCH = SCHEDULE THRU DEC 31 (ALL) (1,24) (1) ..

\$* REPORT BLOCK FOR ZONE TEMPERATURE, CFM, AND ZONE COIL HEATING WITH
 VARIABLE LIST 6,14,32

RS-EA = R-B V-T = EASTROOM-A V-L = (15,16,1,6,14,32) ..
 RS-SA = R-B V-T = SOUTHROOM-A V-L = (1,6,14,32) ..
 RS-WA = R-B V-T = WESTROOM-A V-L = (1,6,14,32) ..
 RS-IA = R-B V-T = INTROOM-A V-L = (1,6,14,32) ..
 RS-EB = R-B V-T = EASTROOM-B V-L = (1,6,14,32) ..
 RS-SB = R-B V-T = SOUTHROOM-B V-L = (1,6,14,32) ..
 RS-WB = R-B V-T = WESTROOM-B V-L = (1,6,14,32) ..
 RS-IB = R-B V-T = INTROOM-B V-L = (1,6,14,32) .. \$1,6,14,32
 RS-EAL = R-B V-T = END-USE V-L = (1) ..

HOURLY-SYSTEMEA = HOURLY-REPORT
 REPORT-SCHEDULE = S-REPORT-SCH
 REPORT-BLOCK = (RS-EA)
 OPTION = PRINT ..

HOURLY-SYSTEMIA = HOURLY-REPORT
 REPORT-SCHEDULE = S-REPORT-SCH
 REPORT-BLOCK = (RS-IA)
 OPTION = PRINT ..

HOURLY-SYSTEMSA = HOURLY-REPORT
 REPORT-SCHEDULE = S-REPORT-SCH
 REPORT-BLOCK = (RS-SA)
 OPTION = PRINT ..


```

HOURLY-SYSTEMWA  = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-WA)
                   OPTION             = PRINT ..

HOURLY-SYSTEMEB  = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-EB)
                   OPTION             = PRINT ..

HOURLY-SYSTEMIB  = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-IB)
                   OPTION             = PRINT ..

HOURLY-SYSTEMSB  = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-SB)
                   OPTION             = PRINT ..

HOURLY-SYSTEMWB  = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-WB)
                   OPTION             = PRINT ..

$* REPORT BLOCK FOR AHU CFM,OA RATIO,TOTAL FAN KW,SF-KW,RF-KW,HCOIL-
T,CCOIL-T (17,39,33,49,50,1,2)
$RS-AB           = R-B V-T = AHU-B           V-L = (17,39,33,49,50,1,2) ..

$HOURLY-SYSTEM2  = HOURLY-REPORT
$                REPORT-SCHEDULE  = S-REPORT-SCH
$                REPORT-BLOCK      = (RS-AB)
$                OPTION             = PRINT ..

$* REPORT BLOCK FOR COOLING COIL ENERGY INPUT AND TOTAL ZONE HEATING
ENERGY INPUT (6 & 7)
RS-SYA           = R-B V-T = AHU-A           V-L = (17,39,3,2,4,6) ..
RS-SYB           = R-B V-T = AHU-B           V-L = (17,39,3,2,4,6) ..

HOURLY-SYSTEMA   = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-SYA)
                   OPTION             = PRINT ..

HOURLY-SYSTEMB   = HOURLY-REPORT
                   REPORT-SCHEDULE  = S-REPORT-SCH
                   REPORT-BLOCK      = (RS-SYB)
                   OPTION             = PRINT ..

END ..

COMPUTE SYSTEMS ..
STOP ..

```


Appendix B: Uncertainty Analysis

For every experiment, there are errors that are associated with the measured parameters. Experimental error is the variation among observations and measurements that are treated alike. The errors for the experimental parameters measured at the ERS were quantified using information obtained from calibrations and corrections, manufacturer information, and current literature. The error values were used to estimate the experimental error for calculated quantities in the experiment. This was done using a Propagation of Error formulation.

Calibration Information

An extensive set of calibrations was performed at the ERS for the resistant temperature devices (RTD) at the ERS (Wen and Smith, 2001). In this procedure, the measurements from the individual RTDs were compared with a Hart 1522 thermometer, the so-called gold standard. The calibration results from this endeavor were used to quantify the portion of the error for the RTDs. A sample of the temperatures used for the final calibration check was used for regression to perform a regression analysis. Ninety-five percent uncertainty bands were calculated to quantify the part experimental error linked to the calibration. Figure B1 shows the plot with a linear regression analysis and the uncertainty bands for the mixed air temperature for the “A” system.

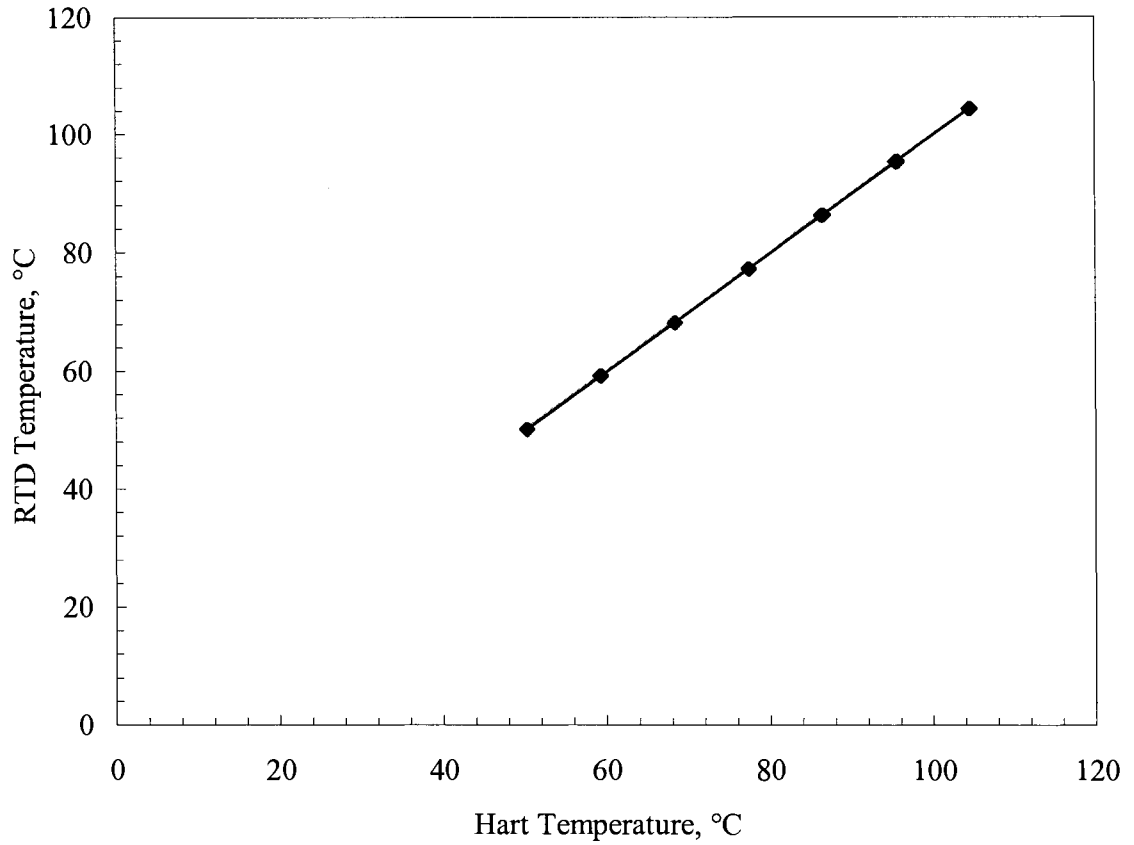


Figure B1: Hart temperature versus RTD temperature with 95% uncertainty bounds.

From Figure B1, the uncertainty bands are small, primarily due to good correlations. The linear relationship between the Hart and the RTD temperatures is shown in Equation B1. Tables B1, B2, and B3 contain information from the regression analysis for the temperatures.

$$T_{RDT} = 0.9967529 T_{HART} - 0.063006 \quad (B1)$$

where

T_{RDT} is the temperature of the RTD, in °C.

T_{HART} is the temperature of the Hart thermometer, in °C.

Table B1: Summary of the fit for the temperature calibration.

Term	Estimate
R-Square	0.999975
R-Square Adjusted	0.999974
Root Mean Square Error	0.091288
Mean of Response	77.29286
Observations	216

Table B2: Analysis of variance for the temperature calibration.

Source	Degrees of Freedom	Sum of Squares	Mean Square
Model	1	70,050	70,150.21
Error	214	1.781	0.0083823
Corrected Total	215	70,152	

Table B3: Parameter estimates for the temperature calibrations.

Term	Estimate	Standard Error	t Ratio	Prob> t
Intercept	-0.063006	0.027358	-2.30	0.0222
X-Component	0.9967529	0.000343	2903.2	0.0000

The associated error from the RTD was calculated from a 95% uncertainty bands. The temperature variance with respect to the gold standard was calculated using Equation B2.

$$\sigma_{Hart} = \frac{\pm N\sqrt{MSE}}{\beta_1} \quad (B2)$$

where

N is the Gaussian distribution quantity for a 97.5% quantile.

MSE is the mean squared error value.

β_1 is the slope of the line from the regression analysis.

There were also small measurement errors for the Hart thermometer quantifies by the manufacturer. The manufacture error values are for the ERS are shown in Table B7. To assign a 95% interval of uncertainty for the temperature parameter, Gleser (1998) proposed a method for dealing with different types of errors variances, which is shown in Equation B3.

$$\sigma_{Total} = \sqrt{\sigma_{Hart}^2 + 1.96^2 \sigma_{Hart,error}^2} / 3 \quad (B3)$$

where

$\sigma_{Hart,error}$ is the error bounds for the Hart thermometer provided by the manufacture.

Similar analyses for two additional RTDs were performed. There were very minute discrepancies. Therefore, the relationship developed for the mixed air RTD for the “A” system was used for the all the RTDs in the experiments.

Corrected Data

Immediately following the Daylighting Case II experiment, discrepancies were realized for the room airflow rates. An experimental apparatus was assembled to measure the airflow rates in the duct using a pitot tube traverse at low airflow rates and a flow hood for high airflow rates. These values were compared with the building control’s airflow rate measurements. A correlation with building control measurements and a regression analysis was performed to correct measurement errors. The linear relation from the regression analysis was used to post-process the room airflow measurements. Figure B2 shows the results of the regression analysis for the East “A” airflow rates. Ninety-five percent uncertainty bounds were used for the error calculations.

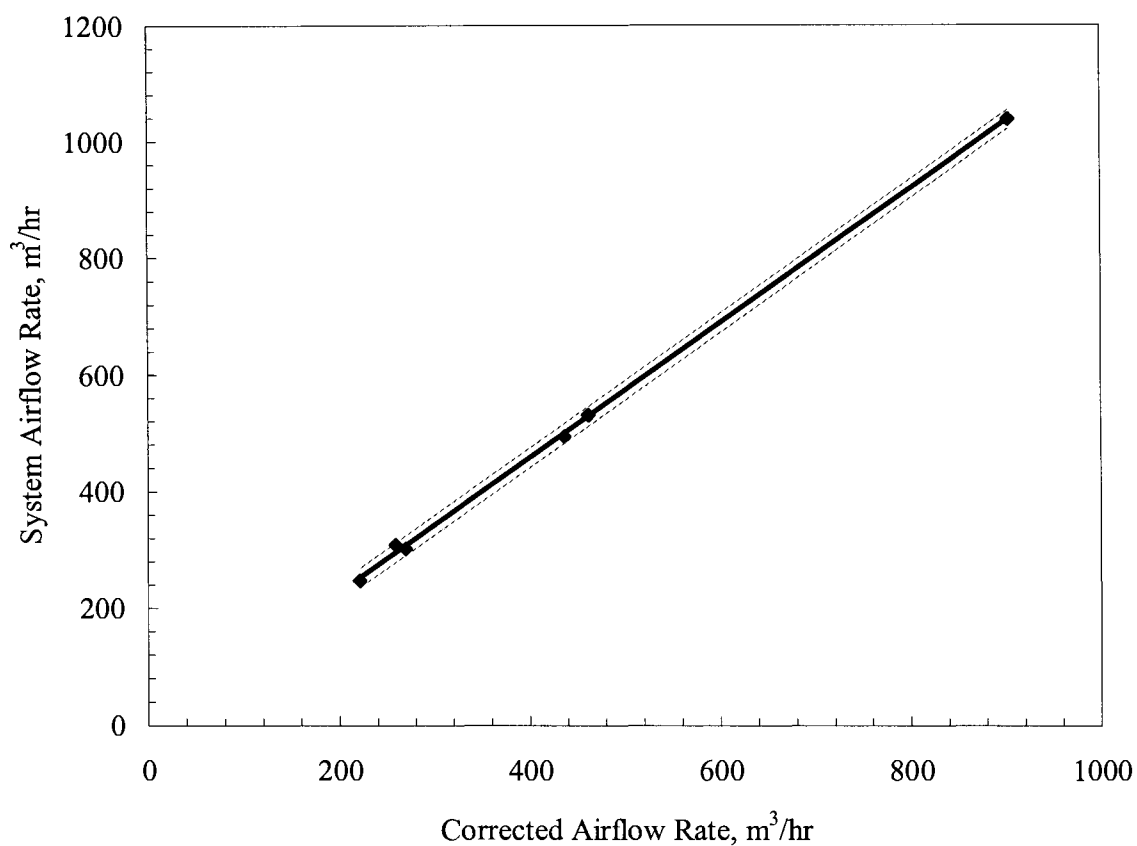


Figure B2: East “A” test room airflow rate correction curve.

Equation B4 is the linear fit from the regression analysis. Tables B4, B5, and B6 contain the results from the regression analysis.

$$Q_{system} = -2.565086 + 1.151116 Q_{Cor} \quad (B4)$$

where

Q_{Cor} is the airflow rate measured by the system in m³/hr.

Table B4: Summary of the fit for the airflow rate correction.

Term	Estimate
R-Square	0.999361
R-Square Adjusted	0.999201
Root Mean Square Error	8.276338
Mean of Response	486.8506
Observations	6

Table B5: Analysis of variance for the airflow correction.

Source	Degrees of Freedom	Sum of Squares	Mean Square
Model	1	428,496.32	428,496
Error	4	273.99	68
Corrected Total	5	428,770.32	

Table B6: Parameter estimates for the airflow correction.

Term	Estimate	Standard Error	t Ratio	Prob> t
Intercept	-2.565086	7.05027	-0.36	0.7344
X-Component	1.15116	0.014554	79.09	<.0001

Similar regressions analyses were performed to correct the airflow rates for the other test rooms. The error from post-processing of the data is estimated by Equation B5. A 95% uncertainty bound was used to calculate the error value.

$$\sigma_{Flow} = \frac{\pm t\sqrt{MSE}}{\beta_1} \quad (B5)$$

where

t is the student distribution quantity for a 97.5% quantile.

MSE is the mean squared error value.

β_1 is the slope of the line from the regression analysis.

Base on literature about airflow rate measurement with a pitot tube traverse and flow hoods, the error is 1-5% of the measured value (Schroeder et al, 2000). Therefore, the total error for the airflow rates for Daylight Case II was estimated in a similar manner as the temperatures. This relationship is shown in Equation B6.

$$\sigma_{Total Flow} = \sqrt{\sigma_{Flow}^2 + (1.96(0.01Q_0))^2} \quad (B6)$$

The statistical parameter used to calculate the 95% uncertainty bounds for the test rooms are shown in Table B7.

Table B7: Statistical parameters for uncertainty bound calculations for zone airflow rates.

Location	n	MSE	β_1
East "A"	6	68	1.151116
East "B"	6	342	1.2283747
South "A"	6	279	1.1173097
South "B"	5	218	1.108725
West "A"	6	178	1.1540728
West "B"	5	144	1.1849076
Interior "A"	6	408	1.0939741
Interior "B"	6	1319	1.1321554

Propagation of Error

Several parameters that were compared with output from the building simulation software were not measured directly during the experiment. These values were later calculated as functions of measured experimental parameters. The calculated quantities included: room reheat power and cooling heat transfer rate. The calculations for the reheat power and the cooling heat transfer rate are described in Equations 5.2.1 and 5.2.2, respectively.

The reheat energy for the zone was calculated using the propagation of error. Equation B7 describes how the error was calculated.

$$\sigma_{reheat}^2 = \left(\frac{\partial q_{zone}}{\partial p} \sigma_p \right)^2 + \left(\frac{\partial q_{zone}}{\partial Q_{zone}} \sigma_{Q_{zone}} \right)^2 + \left(\frac{\partial q_{zone}}{\partial T_{EAT}} \sigma_{T_{EAT}} \right)^2 + \left(\frac{\partial q_{zone}}{\partial p} \sigma_p \right)^2 + \left(\frac{\partial q_{zone}}{\partial c_p} \sigma_{c_p} \right)^2 + \left(\frac{\partial q_{zone}}{\partial T_{DAT}} \sigma_{T_{DAT}} \right)^2 + \left(\frac{\partial q_{zone}}{\partial T_{EAT}} \sigma_{T_{EAT}} \right)^2 \quad (B7)$$

Similar calculations were made for the cooling heat transfer rate. The system airflow rate was calculated by summing the room airflow rates. Thus the errors associated with the rooms impacted the system airflow rate calculation.

The average error for a given experiment was calculated by taking the arithmetic mean of the hourly errors. These values are provided in the comparison tables from the results section of each compared parameter contained within the main body of the report. For many quantities, it was impossible to perform statistical analyses and estimate of uncertainty.

Therefore, many error values were estimated using manufactures information or information from current literature. This information is contained in Table B8.

Table B8: Accuracy of ERS instrumentation.

Name	Units	Uncertainty
HART 1522 Thermometer	°C	± 0.0025
Outside Airflow Rate	ft ³ /min	$\pm 2\%$ of Reading (> 500 ft ³ /min) $\pm 10\%$ of Reading (< 500 ft ³ /min)
Room Airflow Rates	ft ³ /min	$\pm 2\%$ of Reading
Room Light Power	W	$\pm 0.2\%$ of Reading
Barometric Pressure	millibars	± 0.75 millibars
Outside air humidity	% RH	$\pm 2\%$ of RH
Pyranometer	Btu/(hr-ft ²)	$\pm 0.5\%$ of Reading
Pyrheliometer	Btu/(hr-ft ²)	$\pm 0.5\%$ of Reading
Wind Direction	°	$\pm 1^\circ$
Wind Speed	mph	± 1 mph
Constant Specific Heat for Air	J/kg-K	$\pm 2\%$ of Reading

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